ENVIRONMENTAL ATLAS AND MULTI-USE MANAGEMENT PLAN FOR SOUTH-CENTRAL LOUISIANA

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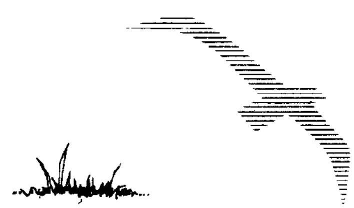

REPORT 18
VOLUME 1

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HYDROLOGIC AND GEOLOGIC STUDIES
OF COASTAL LOUISIANA

Environmental Atlas and Multiuse Management Plan for South-Central Louisiana

Report No. 18
Volume I

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October, 1973

Prepared for

Department of the Army, New Orleans District
Corps of Engineers, Contract No. DACW 29-71-C-0219

and

Office of Sea Grant, National Oceanic and Atmospheric
Administration of U. S. Department of Commerce,
Institutional Support Grant No. 04-3-158-19

ABSTRACT

The normally difficult problems of resource management and land use planning are further complicated in the coastal zone by the complexity of the natural setting, rich resource base, and trends of population increase. The Louisiana coast, dominated by the Mississippi River delta system, illustrates the classic elements of the problem. The area is exceptionally high in biological productivity. Unique natural beauty and a rich cultural heritage further identify these lowlands as a nationally important resource. As the origin and ecology of the region are products of deltaic processes, it can appropriately be described as a self-maintaining natural system.

Human activity has seriously altered the natural balance of this system. Massive environmental degradation has occurred during the past thirty years and the entire system may soon collapse. Primary causes of deterioration include: 1) flood control and navigation improvement; 2) mineral extraction; 3) accelerated subsidence; 4) urban encroachment into wetlands; 5) water pollution.

The problem of restoring the system's balance while allowing for projected growth and development has been addressed, and a multiuse management plan, based on analysis of natural and human processes operating in the area and land use suitability, has been proposed. Highways and other public works projects provide the mechanism for directing growth and development to environmentally suitable areas. Renewable resource areas are identified, and management priorities and guidelines outlined. A water resource management program calls for conservation of local runoff as well as directing the Mississippi River water and sediment for environmental maintenance and enhancement.

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ACKNOWLEDGEMENTS

The support of the New Orleans District U. S. Army Corps of Engineers and the Office of Sea Grant, National Oceanic and Atmospheric Administration is gratefully acknowledged. Primary funding was provided through Corps of Engineers Contract DACW 29-71-C-0219 for development of methodology and study of the Terrebonne Parish pilot area. Supplementary funding, Office of Sea Grant, Institutional Support Grant No. 04-3-158-19 made it possible to extend the scope of the project to include the des Allemands-Barataria Basin.

INTRODUCTION

The Barataria-Terrebonne region of south central Louisiana (Figure 1-1) comprises the most extensive and most productive natural entity within the Louisiana coastal zone. It owes this productivity to a viable estuarine environment, a subsurface rich in mineral deposits, and a topography that greatly facilitated access and allowed for agricultural and industrial development. At the same time, beauty of the natural setting of the area cannot be overemphasized. The natural levee ridges, swamps, marshes, bayous, lakes, bays, and islands represent a unique coastal landscape that provides scenic open space and unlimited opportunities for recreation. This potential is further enhanced by an abundance of archaeological and historic sites, and a rich folk culture.

With regard to extended prosperity of the area, the estuarine environment is its most important asset. A repetitive sequence of delta building and abandonment has produced a series of estuaries whose biologic productivity sustains a multi-million dollar commercial fisheries industry. Louisiana landings rank first nationally in volume and third in value, with shrimp, menhaden, and oysters the dominant catches.

To a large extent, continuity of this resource is dependent on quality and quantity of the estuarine nursery areas. In both respects, the Barataria and Terrebonne estuaries rank among the highest, state and nation-wide. However, viability of the nursery area is critically dependent on a balance between fresh and salt water influx to maintain a desirable salinity regime, between erosion and deposition to

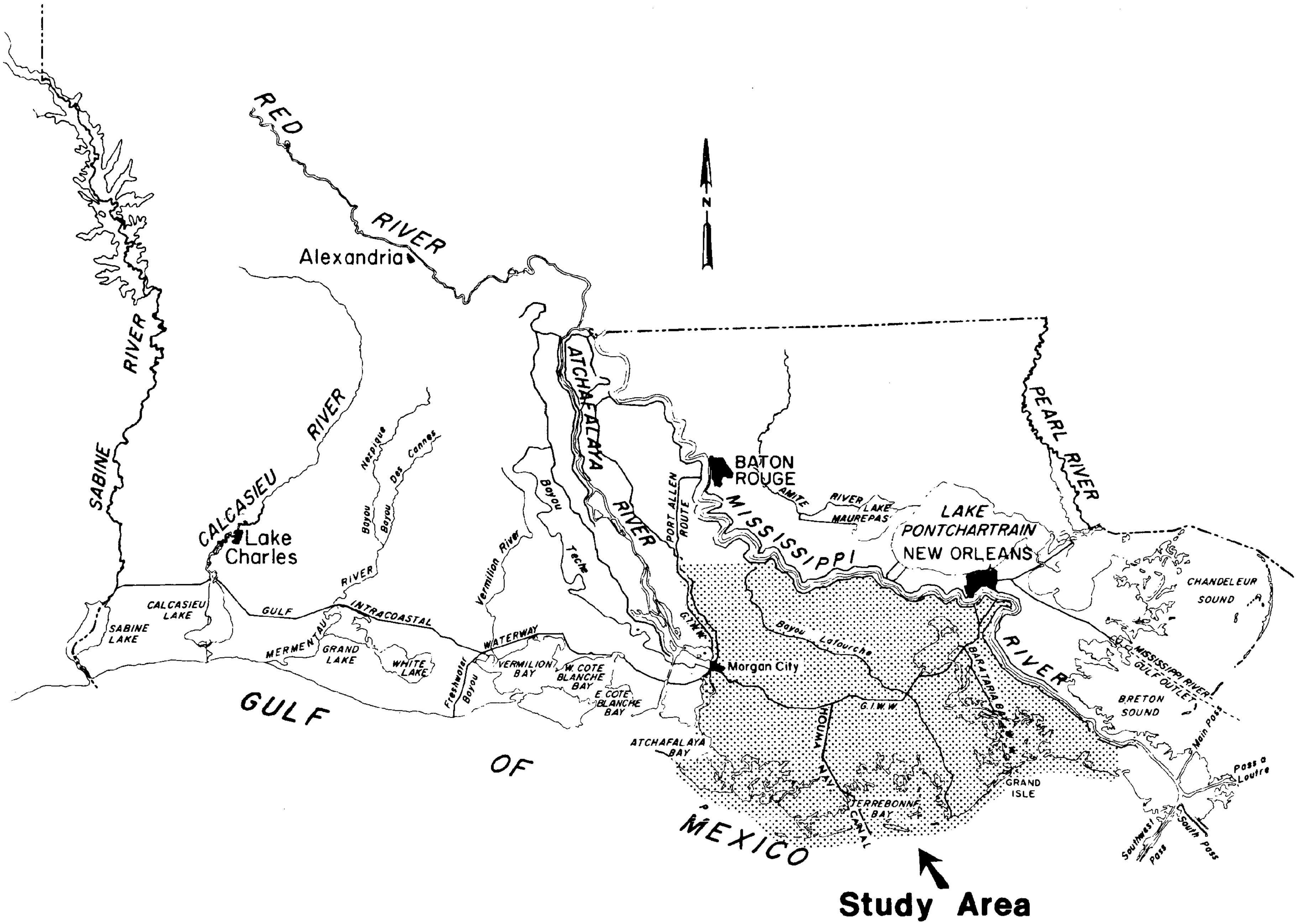


Figure 1-1. South-central Louisiana study area and its relationship to the Louisiana coastal zone.

maintain an optimum land-water ratio and length of land-water interface, and on health of the marshes as a source of organic detritus and a deterrent to rapid areal increase of water bodies at the expense of the marshlands. This dependence translates into a highly complex and highly vulnerable environment whose value as a resource can be maintained only through recognition of both its potentials and limitations.

As documented by archaeological evidence, man has lived in the Barataria-Terrebonne region for thousands of years. Until the early twentieth century, technology and economic opportunities made his presence and activities compatible with his natural environment. Settlement, industrial development, and land transportation patterns were dictated by natural levee ridges. Regional centers, such as the city of Houma, developed where major levees converged. The arable nature of these same natural levees allowed the area to become an agricultural center for sugar cane. The estuaries, as now, sustained a fisheries industry, while natural waterways, including the Mississippi River, adequately served water-borne transportation. With economic growth and technologic progress came, however, the demands and possibilities for flood protection, extraction of mineral deposits, land reclamation, urban development, and transportation networks, and resulting obliteration of natural boundaries and a dissection of natural entities.

In particular, the confinement of the Mississippi River, the extraction of mineral deposits, and industrial and urban sprawl have placed the wetlands under severe stress through modification of the geologic and hydrologic regimes. Though unavoidably a part of regional resource development, prevention of overbank flow from the

Mississippi River has deprived the estuarine system of needed sediment, fresh water, and nutrients. At the same time, subsidence and wave erosion continued to convert land into water, and saline Gulf waters continued to intrude. Mineral extraction demanded a vast network of canals to accommodate drilling operations and transport. Canal dredging again modified the hydrologic and salinity regimes by reducing fresh water diffusion, altering circulation patterns, and providing avenues for salt water encroachment upon the brackish marshes. These as well as other developments represent a serious conflict between exploitation of renewable and nonrenewable resources. Insufficient recognition and evaluation of this conflict threatens to sacrifice long-term benefits for short term profits.

It is only through adherence to a sound long-term plan for land use and resource development that the natural wealth of the coastal zone can materialize to its full potential. Such a plan can be established through detailed inventory of the natural environment, identification of those elements and processes which make the area unique and highly productive, and an evaluation of man's impact on the natural system. This approach is followed in the present study. On the above basis, the study has resulted in a series of guidelines for resource exploitation and multi-use development of the Barataria-Terrebonne region.

APPROACH

Background of Study

In the 1960's there was an increasing concern about environmental effects of a number of major projects proposed for the Louisiana coastal zone. By 1969, in an effort to meet the challenge of maintaining a viable natural setting and still responding to the demands of a highly industrialized and urbanized society, the New Orleans District Corps of Engineers initiated five studies of special environmental significance, the coastal area being an important concern of each. In addition, the New Orleans District chaired an interagency study, collectively referred to as the Fish and Wildlife Study of the Louisiana Coast and Atchafalaya Basin Floodway, which was related to and supported the five studies. The Center for Wetland Resources, Louisiana State University, was retained by the New Orleans District to undertake hydrologic and geologic studies as part of the Fish and Wildlife Study. Following initial engagement in these investigations, the relationship has continued, and this report results from the fourth in a series of contract studies addressing the general problem of management and development of the coastal zone.

The studies have progressed through several distinctive phases. Initial emphasis was on understanding the natural processes and forms of the Mississippi Delta System as related to geology, ecology, hydrology, water chemistry, water balance, and runoff, and the synthesis of available data. A primary objective was problem definition. Map and aerial photo studies established rates and extent of land loss, marsh deterioration, and coastal erosion, and demonstrated that the delta system, comprising most of the coastal zone, was generally in a serious condition of deterioration. Contributing factors, both natural and man-induced, were identified. Studies of salt water intrusion, as well as subsidence, flood control, drainage projects, land reclamation, dredging, and urban and industrial encroachment into the wetlands have led not only to a better understanding of the environmental problems, but have also provided the basis for management guidelines and the development of a management plan. The initial plan is presented in this report and follows creative approaches to environmental problems and future uses of the coastal area.

Whereas previous work has dealt with macrosystems, primarily the delta system of the Mississippi River, the present study has been conducted at an intermediate scale. It focuses on two major hydrologic or estuarine units which are subsystems of the delta. The Terrebonne Parish area was selected for a pilot study of this assessment of the coastal zone management problem because it was considered to be typical of much of the Louisiana coast. It is also of particular interest because of high biological productivity and a relatively low level of human impact. After the study was initiated, however, it became apparent that management problems within the proposed study area were intimately linked with those of neighboring lowlands. Supplementary support from the Office of Sea Grant made it possible to expand the scope of the study and include the entire area between the Mississippi River and the east levees of the Atchafalaya Basin Floodway. It should again be emphasized that this is an intermediate scale study, and that there are several levels of higher resolution in the planning hierarchy that eventually must be considered.

Throughout the studies that have led to projection of a management plan for south central Louisiana, emphasis has been placed on development of a methodology for environmental evaluation. The subject area of environmental evaluation has progressed significantly in recent years, and the use of environmental data in planning is now a well-accepted technique (see, for example, McHarg, 1969). The approach recognizes that Louisiana's coastal zone is unique in both natural landscape and cultural processes, and has used these inherent qualities and values as a basis of projection.

The natural setting of the coastal zone of Louisiana can be summed up in one word, "dynamic". The fact that the area is in a state of constant flux causes many problems, but at the same time offers many opportunities. The coastal environment is the product of interaction between the deltaic-fluvial system of the Mississippi River and marine forces of the Gulf of Mexico. Associated with incessant subsidence, the interplay between deltaic and marine processes has resulted in a highly diversified landscape of natural levees, swamps, marshes, bayous, lakes, bays, and barrier islands, all in a changing and constantly evolving relationship.

Changes are often so rapid and seemingly so complex that one might view them as random and unpredictable, but that is not the case. Over the years, a good understanding of the relationships between process, materials and form that occur in the coastal area has been developed. It is now possible to predict with a high level of confidence the probable effect of any major modification upon the environment. It is this prediction capability that permits the development and selection of possible alternatives for the future use and management of our resources.

The inherent values of the coastal zone are many and varied, and it is the retention and development of these values that makes planning essential. Economic values have been well-documented, and have become evident in, for example, oil and mineral extraction industries, commercial fisheries, and the trapping of fur animals. Major cities, dependent upon connection to the Gulf and inland areas, have developed at high land points or on the fringes of the wetland areas. Of no less value, the coastal zone is a scenic, historic, and recreational source. Other renewable resource values include storage of surface and ground water, and wildlife habitats.

Early European settlers and more modern civilizations have tended to make extensive and often wise use of land as they settled, farmed, and developed the levee lands, and fished and hunted in the wetlands. Road and water transportation have long played a major role in development of the region and are essential components . In more recent times, as man has tried to overcome the hazards of floods and storms, and as extraction of subsurface minerals and use of other resources have become more pressing, the environmental base has come to show signs of serious, perhaps irreversible stress. There is a real danger that many of the values traditionally cherished by the people are being threatened or lost through environmental and cultural pressures. This requires a coastal zone management plan that achieves a compatible relationship between the land base and the needs of the people, one which will be mutually beneficial now and in the future.

In concept, such a plan must recognize the environmental opportunities and constraints, as well as the need for man to make adaptations of the environment for his successful use and occupation of the land. But it should point out that man should use restraint in manipulating the environment if it is to continue returning long-term values to him, as a user and a steward of the land. This study has attempted to arrive at such a plan for the south central area of the Louisiana coastal zone.

Essential to successful management is the organization of environmental data in a way that aids in the decision-making process. To this end, the overall study approach included the following steps:

1. Define natural systems in the study area and identify processes, forms, and materials which characterize the systems.
2. Inventory environmental and land use data for the study area; determine natural and man-induced environmental succession; and identify indices of change and quantify wherever possible.
3. Based on natural and man-made features, define management and development areas.
4. Recommend future land use and management for each area, with priorities for development and preservation.
5. Devise a surface water management plan compatible with recommendations in Number 4.
6. Identify existing and proposed projects which conflict with Numbers 4 and 5, and make recommendations for reducing impact of conflicting projects.

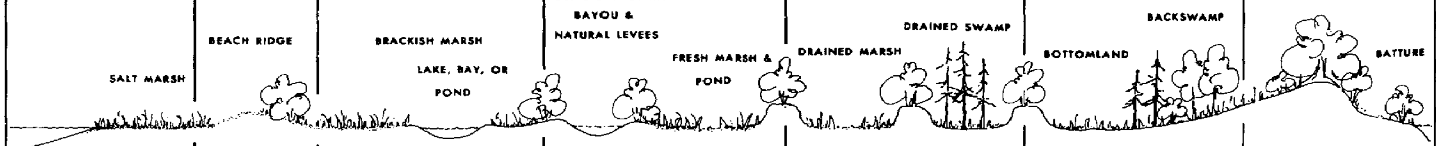
Environmental and Land-Use Atlas

Systematic consideration of spatial aspects of processes, materials, and forms was accomplished by compiling data in atlas format. Data were assembled on base maps at a scale of 1:250,000 and reduced for presentation in the report. The atlas (Volume II) is not intended to be all-inclusive; rather, key geological, geographical, and ecological elements and processes have been selected which weigh heavily in the planning process. Each plate in the atlas is intended to be self-contained. Additional sheets will be added in the future as funds, needs, and data become available.

For example, soil conditions are clearly of primary importance in determining land-use suitability in the Louisiana coastal area (Plate 8). Fortunately, soils have been systematically classified and mapped throughout most of the study area. Their characteristics have been defined and they have been evaluated from the standpoint of opportunities and constraints related to specific uses (Fig. 2-1). Further, the distribution of soils mirrors that of landforms. For these reasons, the soils map has been included in the atlas.

The distribution of faults and salt domes (Plate 14) was included because they represent environmental constraints and opportunities. Occurrence of mineral deposits is controlled to a large extent by these structural features. They are important in determining foundation stability. Salt domes may be of considerable importance in the development of underground storage or waste treatment chambers.

The vegetation and oyster maps (Plates 9 and 10) show the distribution of important biological indicators. Involving sessile organisms, they reflect specific ranges of ecological conditions. Certain organisms are so selective that they become indices of a certain environmental condition or habitat. Their distribution, in that case, defines the extent of the habitat and changes in their distribution through time reflect changing ecological conditions. The distribution of oysters is indicative of conditions of water chemistry, turbidity, temperature, and



SOILS	SALT MARSH	BEACH RIDGE	BRACKISH MARSH / LAKE, BAY, OR POND	OLD DISTRIBUTARY BAYOU & NATURAL LEVEES	FRESH MARSH & POND	DRAINED MARSH	DRAINED SWAMP	BOTTOMLAND	BACKSWAMP	LEVEE	BATTURE
SOIL ASSOCIATION	UNDRAINED SALTWATER MARSH	SAND	BRACKISH MARSH	COMMERCE CYPREMORT CONVENT mhoon gallion baldwin sharkey iberia dundee	UNDRAINED FRESH WATER MARSH	DRAINED FRESH/SALT MARSH	DRAINED SWAMP	UNDRAINED SWAMP	SHARKEY-SWAMP Tunica Baldwin Barbary Maurepas	COMMERCE CYPREMORT CONVENT mhoon iberia baldwin	LOAMY ALLUVIAL convent-silty convent-loamy alluvial
GENERAL SOIL CHARACTERISTICS	organic layer of various thicknesses underlain by soft dispersed saline clays and mucky clays with separation when flooded; peat or muck underlain by slightly firm to semi-fluid clays and some fine sands. permanently high water table	fine sands mixed with shell fragments	unstable organic material of varying thicknesses underlain by silty clays with separation when flooded. permanently high water table	silt loam surface silt clay loam subsoil black organic material 2-8' thick over soft clay;some flotation. permanently high water table	unstable; organic material several feet thick underlain by silty clays with separation when flooded;	organic material several feet thick underlain by clay; some thin loamy fill material.	thin organic surface underlain by clay, with some 1-several feet thick portions loamy fill.	thin organic surface underlain by clay; with spots of thick organic material; organic surface layer 1 to several feet thick over firm semi-fluid clays. permanent high water table	clay surface and subsoil underlain below 25" by loam; flooded most of time; loamy fill.	silt loam surface; silt clay loam subsoil	stratified silt loam; very fine to fine loamy.
SUITABILITY											
TOP SOIL	not suitable	not suitable	not suitable	good-fair	not suitable	not suitable	not suitable	not suitable	not suitable	good-fair	fair
HIGHWAY SUBGRADE	not suitable	fair	not suitable	fair-poor	not suitable	not suitable	not suitable	not suitable	not suitable	fair-poor	good-fair
HIGHWAY SUBBASE	not suitable	fair	not suitable	fair	not suitable	not suitable	not suitable	not suitable	not suitable	fair	fair
RESIDENTIAL FILL	not suitable	not suitable	not suitable	fair-poor	not suitable	not suitable	not suitable	not suitable	not suitable	fair-poor	fair
SAND OR SHELL (subsurface feature)	not suitable	good	not suitable	not suitable	not suitable	not suitable	not suitable	not suitable	not suitable	not suitable	good-fair
DEGREE OF LIMITATION											
HOMESITES (1-2 story)	very severe	severe	very severe	slight to moderate	very severe	severe	slight to severe	severe very severe	very severe	slight to moderate	
LIMITED INDUSTRY with community sewage system	very severe	severe	very severe	moderate to severe	very severe	severe	slight to severe	severe very severe	severe	moderate to severe	
LANDSCAPE-GARDENS-LAWNS	very severe	severe	very severe	slight to moderare	very severe	severe	slight to severe	severe very severe	severe	slight to moderate	
PLAYGROUNDS-PICNIC AREAS	very severe	severe	very severe	moderate to severe	very severe	severe	slight to severe	severe very severe	severe	moderate	
STREETS-ROADS-AIRPORT RUNWAYS	very severe	severe	very severe	moderate	very severe	severe	slight to severe	severe very severe	severe	moderate	
CAMPSITES-GOLF FAIRWAYS	very severe	severe	very severe	slight to moderate	very severe	severe	slight to severe	severe very severe	severe	slight to moderate	
ENGINEERING CHARACTERISTICS											
subsidence potential	high	low	high	low	high	very high		medium		low	
shrink-swell potential	low to high	none	high	high	low - high	high		high	high	very - moderate	
bearing strength 1-2 story buildings	low - very low	high	low - very low	low	low - very low				low	low - moderate	
corrosion potential	high		high	high	high					moderate	
MANAGEMENT	DUCKS DEER	seashore birds	DUCKS DEER	CRAWFISH	DEER DUCKS	DUCKS	DUCKS DEER	DEER DUCKS CRAWFISH, RABBITS	DEER, DUCKS TURKEY, SQUIRRELS QUAIL	HARBOR FACILITIES MARINE-TYPE INSTALLATIONS DUCKS, SQUIRRELS RABBITS, DOVES, QUAIL	
DRAINAGE FACTORS	near sea level flooded - saline tidewaters	flooding	poorly drained near sea level	poorly drained wet to moderately wet	near sea level flooded	poorly drained	poorly drained	near sea level	poorly drained infrequent floods	slightly wet	
EXISTING USEAGE	wildlife habitat	bird sanctuary	wildlife recreation	residential, cultivated crops, urban, pasture, industrial	livestock, on stable areas wildlife habitat	pasture/range sugarcane, urban industrial	urban, industrial woodland, being cleared	wildlife habitat cropland, pasture, urban, industrial		recreation, residential crops, urban, pasture, industrial, flood retention, woodland, wildlife, borrow fill	

Figure 2-1. Schematic cross-section of soil associations showing land-use suitabilities and limitations as associated with the natural environments of the Barataria-Terrebonne area.

nutrient supply that are ideal for many important estuarine organisms. Oyster distribution, then, becomes an index for prime estuarine conditions. Since surveys of the distributions of organisms themselves are not available, the lease files of commercial oyster beds of the Louisiana Wild Life and Fisheries Commission become the next best source of data.

The transportation and oil and gas maps (Plates 17 and 15) represent elements of land use that are particularly important in considerations of environmental management. Highways, railroads, and mineral industry access and pipeline canals often conflict with natural circulation and runoff patterns. There are often a number of secondary stresses associated with these activities.

Unique environments (Plate 13) shows the distribution of parks, game management areas, archaeological sites, and streams designated by the state legislature as scenic rivers and waterways. This map is useful not only in evaluating the impact on these special places and features in reference to proposed projects, but also reveals clusterings that become important in considering future regional recreational needs.

Plates 4-7 and 11 deal with various aspects of hydrology and water chemistry. The hurricane storm surge map (Plate 11) indicates the extent of flooding and maximum wind velocities associated with Hurricane Betsy, which struck the study area in September of 1965. Hurricane Betsy was selected as a case study because it was a very severe storm whose track bisected the study area. The plate also shows the extent of high ground and flood protection levees. The maps dealing with precipitation, precipitation excess, and salinity (Plates 4, 5, 6, 7) provide important input in the development of a water management plan.

The canal map (Plate 16) can appropriately be described as an impact map. It illustrates, in quantitative terms, the extent of canal dredging in the study area.

Plates 18-22 summarize an approach to management of the area and will be discussed at length in another section of this report.

Grid Cell Data Collection and Display

Several techniques have been formulated for handling quantitative process and inventory data. These techniques relate primarily to climatic and hydrologic data and to relative magnitude of man-induced hydrologic changes in the coastal zone. One form of output consists of computer-printed contour maps the same scale and format as other process and land-use maps in this atlas.

A data-cell concept has been utilized for organization and display. The initial step in the system, data collection, was formulated by setting boundaries for the study area and subdividing the area into data collection cells or units, based on the Louisiana Coordinate System - South zone (Plate 2). This yielded a total of 1562 square cells, each being 10,000 feet on a side, and located by latitude and longitude. Once established, the cells become the working units for collecting, as well as organizing, reducing, and manipulating the environmental data.

One application of the data-cell system was in an inventory of man-made water bodies. Basic data were derived from U.S. Geolcgical Survey topographic maps at a scale of 1:24,000 (7 1/2-minute quadrangles, various dates), controlled aerial photo mosaics (Amman International Corporation, 1956) at the same scale and format, and uncontrolled mosaics (U.S. Army Corps of Engineers, 1969). A transparent overlay with cell boundaries was constructed for each of the 7 1/2-minute quadrangles. Primary use categories were established for man-made waterways, including mineral industry access canals, rig cuts, major pipelines, minor pipelines, lumbering canals, trapping cuts, borrow pits, navigation canals, boat slips, and major and minor drainage canals. The waterway types were color coded and an overlay sheet updated to 1969 was prepared for each quadrangle. Using a map measuring wheel, the waterways were then measured by type for each grid cell, the information being tabulated on coded data sheets. A random sampling of widths by type was taken from the entire area. Width measurements were made on the aerial photo mosaics with the aid of a calibrated optical loupe. Samples included water bodies in all soil types in order to take into account variations introduced by bank instability. The areas of non-linear man-made water bodies were measured by planimeter. All data were entered onto computer cards, and a program was developed to calculate total area for each water body type by cell. A companion program was develcped for computer plotting of the values on atlas base maps. Plate 16 of the atlas shows contours of total canal density in the study area, as well as tabulation of total canal areas by type.

Hydrologic Models

To effectively manage the study area, it is necessary to analyze direction and magnitude of fresh water flow. Although some types of data are plentiful within the study area, there are serious gaps in streamflow and topographic data. Records of streamflow are practically nonexistent, and regular streamflow measuring stations would be very costly to maintain because of the extremely low gradients. There is no precise information on topography. The available topographic maps show a minimum contour interval of five feet, but most of the area is less than five feet above mean Gulf level, making it difficult to estimate water surface slopes. At times, the direction of streamflow is uncertain and it is difficult to distinguish on the map between distributaries and tributaries.

The data availability and hydraulic characteristics of the region dictate the method of treatment. Runoff has to be estimated from rainfall data, and the Thornthwaite-Mather water balance method (Thornthwaite and Mather, 1955) was employed for this purpose. Subsequently, two mathematical models, including a steady- and a transient-state model, have been devised to simulate the runoff through the system (Light _et al._, 1972). In developing the models, computerization was an absolute necessity because of the large quantity of data to be handled and the large number of arithmetic operations. A grid-square technique (Solomon and Denouvillez, 1968) was employed for efficient computer storage and retrieval of data. A series of computer programs was developed to reduce these data to proper form as input, execute the operations of the two models, and display the results in tabular printouts and graphical or map plots.

The grid overlay, consisting of 10,000-foot square cells, was utilized as a framework for data input to the models, each cell being assigned an index number. A total of 1602 cells were required to cover the entire project area, and various meterological, physiographical, and cultural data were compiled for each cell. The data pertinent to this study, consisting of monthly rainfall amounts recorded for the period 1945-70 and land-water ratios, were stored on magnetic tape.

The rainfall compilation by cell was obtained by first assembling the available records at 18 climatological stations in or near the area, filling in the missing amounts by regression, and then interpolating the complete 26-year set of values at the midpoint of each cell. The orographic bias in rainfall is considered insignificant in the area of interest, and a linear 3-station interpolation scheme was used. Land-water ratios were obtained from 7 1/2-minute topographic quadrangles as a measure of the relative proportion of land to total water surface area of all water bodies within the cell, including bays, lakes, swamps, marshes, and channels.

Runoff from land areas and fresh water accretions to water bodies were determined by the Thornthwaite-Mather method based on a soil moisture accounting procedure and on formulas relating moisture losses to rainfall amounts, air temperature, latitude, and season of the year. The method assumes that water losses from water surfaces, both open and vegetation-covered, occur at the potential evapotranspiration rate. These losses are generally greater than the total losses over land and can result in moisture deficits during dry spells, particularly in summer when potential evapotranspiration is high. Recharge computations depend on the assumed saturation capacity of the soil. This capacity is rated at six inches within the project area, based on some measurements made in the clay alluvial soil. Some confirmation of this capacity and the general method was obtained by tests of runoff at a few gaged upland basins outside of, but adjoining the project area.

The Thornthwaite-Mather procedure was programmed to compute the separate land and water components of rainfall excess or deficit in each cell from input of rainfall depth, air temperature, cell latitude, and calendar date. The final step is in the application of the land and water surface areas to the two components to obtain a weighted sum representing the net runoff depth generated within each cell. All the basic data were processed through this manner, resulting in storage of 312 monthly runoff values within each of 1602 cells. The dual computation method employed here is similar to that applied to the Lake Maracaibo basin in Venezuela (Carter, 1955).

Previous regression studies for the area showed a strong inverse correlation between monthly averages of salinity at various measurement sites in the area and monthly averages of fresh water input lagged one to six months. Therefore, it was concluded that a model providing an estimation of the geographic pattern of long-term streamflow averages would be useful in defining the corresponding pattern of mean salinity. Such a model, termed a steady-state model, was constructed to route the runoff generated within each cell through the entire system of cells (Light, et al., 1972). This model consists of a tracking pattern denoting the estimated mean direction and percentage of flow exchange of each cell with the four adjacent cells. This pattern is deduced from examination of topographic maps and aerial photographic mosaics, taking into account the stream configuration, widening or narrowing of the streams along their courses, and the general seaward direction of water travel. The model represents an idealized approximation to the real system of channels, but should provide a reasonably good estimate of streamflow crossing the cell boundary. Since the model is utilized to predict averages for periods of several months or longer, storage and dynamic factors are ignored.

A computer program was developed, utilizing the steady-state model, to determine the mean geographical distribution of fresh water flow over a study area consisting of the region north of the Intracoastal Waterway. Input to this program consists, first, of the tracking pattern translated into a series of coded statements defining the course of flow between junctions. The second input is the series of monthly values for each cell within the study area. The computer averages the depths of runoff for the desired period of time, converts inches of depth to average discharge for the period in cubic feet per second taking cell area into account, and routes the discharge from cell to cell according to the tracking pattern. Output is in the form of a printed table showing routed discharge for each cell, and in the form of a contour map showing isolines of discharge.

A transient-state model was devised to provide information on short-term variations in streamflow and water surface elevations (Light et al., 1972). The model, similar in several respects to those developed for the Mekong (Zanchetti, et al., 1970) and the Sacramento-San Joaquin (Dudley, 1971) deltas, was applied to a 618-square mile test basin consisting of the drainage area of the Bayou Chevreuil above Lake des Allemands. This basin is located in the headwaters region of the project area and is not subject to significant backwater from normal ocean tides. The model incorporates storage and kinematic factors not present in the steady-state model, and produces simulated stage and discharge hydrographs of the rise resulting from heavy rains at selected points in the watershed. As noted previously, no discharge observations are available in the project area for checking purposes. However, there are continuous records of river stage at several locations, and these can be used for calibration and verification of the model.

The transient model involves subdivision of a watershed into a number of zones based on tributary drainage boundaries, and determination of certain physiographic data for each zone (Atlas, Plate19). These data consist of a total area and total water surface area of each zone, the combined width of all channels linking each pair of zones, and distances between centers of mass of linked zones. The test basin, whose water surfaces comprise 62 percent of the total drainage area, was divided into 26 zones.

The hydrologic inputs to the model consist of hourly values of zonal rainfall excess for selected study periods, obtained by analysis of available short period rainfall records and the previously computed monthly runoff amounts for the group of cells comprising the zone. Five periods of heavy rain accompanied by major stream rises were selected for study after examining the daily rainfall record for the past 20 years and the corresponding daily stages recorded at the Chegby river station on Bayou Chevreuil.

A computer program, based on a finite difference integration of the equations of motion and continuity, was developed to execute the computations of the transient model. Stream velocities are very low and inertial forces can be safely ignored, thereby reducing the equation of motion to the Manning formula involving factors of head, hydraulic radius, cross-section area, and a friction coefficient. The time step for the computations varies from one hour for the rising limb of the hydrograph to six hours on the recession.

Total input to model consisted of the physiographic and rainfall excess data noted previously, and certain initial and boundary conditions. The latter consisted of the estimated water surface elevations at each node prior to the rise and a fixed lake elevation at the outlet. In addition, there are certain undetermined parameters that have to be evaluated by a calibration procedure. These consist of a channel friction coefficient, cross-section form, low-water depth in the channel, a storage reduction factor reflecting space occupied in the marshes by submerged vegetation, and a runoff volume correction factor deduced from ratios of areas underneath the two hydrographs.

Output of the model in its present form consist of a tabular and graphical printout of the computed and observed stage hydrographs at Chegby, and a table listing crest stages computed at all nodal points in the model. Some tentative results have been achieved in attempting to obtain the best match of two hydrographs by a series of trial-and-error runs. The optimum shape of cross-section appears to be the wide rectangular type as compared to the triangular or parabolic type, the two other types tested.

As stated previously, once a model is developed and calibrated it can be used as a simulator, either to produce historical extensions of the record or to evaluate the effect of artificial changes in the watershed. In the latter case, flows can be injected at one or more points to simulate diversion of water from outside sources, or the routing scheme can be adjusted to conform with planned construction works in the watershed. Such land or water management changes will affect the stage, discharge, and storage characteristics of flood rises, and may have both detrimental and beneficial aspects. As an example, a simulator run was made on the January-March 1955 flood utilizing the tentative calibration constants previously determined, but assuming a hypothetical 50 percent uniform reduction in channel conveyance, a reduction that might be produced by canal filling. The "before and after" hydrographs indicate that the change would result in a substantial reduction in peak discharge and an increase in water retention at the expense of a slight rise of the flood crest at Chegby. However, computer results for upstream points indicate more substantial increases in stage at those points, and therefore, that a significant increase in flooded area would result from the alteration of the canal system.

Present results of the transient model are preliminary and only cover a portion of the project area. It is expected that the model will undergo changes and that there will be refinements in data processing techniques as the work proceeds. The greatest advance would probably come from the introduction of field observations in place of the present assumptions of hydraulic characteristics of the channel network. It is hoped that these observations will be forthcoming in the near future, and will permit closer correspondence between model and prototype.

Use of Remote Sensing Imagery

Conventional aerial photography and remote sensing imagery provided invaluable primary sources of data for the study. As previously mentioned, aerial photo mosaics were used for measurements of man-made water bodies and construction of a number of the atlas maps. In addition, a number of remote sensing missions by the National Aeronautics and Space Administration have been flown over the entire area and selected parts in recent years. A list of the more important missions is presented in Appendix A.

Of particular value was the imagery acquired during the March, 1972,high altitude overflight. This data provided major input into the overall evaluation of the coastal environment as well as evaluation of specific parameters. It substantially enhanced knowledge concerning the distribution of vegetative communities (Plate 9) and circulation patterns in the bays and coastal waters, as revealed by turbidity contrasts, and allowed updating information on shoreline changes along the barrier islands (Plate 12).

Even though much of the vegetation was dormant because of the winter season, inspection of the imagery allowed differentiation of at least four distinct categories corresponding to cypress-gum swamps, marsh, flotant marsh, and mangroves. Directly related to this differentiation, the imagery aided in delineating the topographic effect of natural levees and crevasse splays.

Contrasts between clear and turbid waters allowed general inferences to be made as to patterns of water movement in the bays and adjacent coastal waters. In particular, the extent, direction, and color density of plumes showing effluent from bays into the Gulf of Mexico revealed distinct patterns of coastal circulation.

With regard to the barrier island system, the imagery not only allowed an updating of shoreline changes, but also provided valuable information as to the occurrence and extent of tidal deltas and the relative magnitude of tidal flow through the tidal inlets between the barrier islands. Both are critical factors governing continuity of longshore sediment drift.

The imagery was invaluable in delineating present land use patterns. The March, 1972, high altitude coverage of the Louisiana coastal zone should be regarded as one of the area's most important historic documents. This type of synoptic regional coverage is so important that it should be repeated at least once every two years.

User Input

User input is an indispensable ingredient in the planning process. Ideally, the procedure for obtaining user input should be formalized so that all interested parties have an opportunity to present their viewpoints. Since the study group did not have the authority to conduct public hearings, the necessary input was obtained by seeking out interested parties and agencies. As a result, a major part of the study effort was devoted to personal interviews, attendance of public hearings, participations in meetings (planning meetings, symposia, and workshops) and presentation of lectures to special interest groups. During the course of the project, direct contact was made with a broad spectrum of local, state and public agencies, representatives of industry, agriculture, landowners, and private citizens. During the last six months of the study, illustrated lectures explaining the project methodology and tentative results were presented publicly to a number of groups for comment and discussion. An attempt was made to consider all criticism and suggestions. A list of primary contacts is included in Appendix B .

NATURAL SETTING

Evolution

The Barataria-Terrebonne region is part of the Mississippi deltaic plain. Its geologic history relates a sequence of delta building and abandonment under a condition of continuing subsidence. With regard to its present surface configuration, building of the area started approximately 3500 years ago with development of the Lafourche delta complex joining and partly overlapping the relict margin of a deteriorated Teche delta to the west (Figures 3-1 and 3-2). Growth of the Lafourche delta was sustained for some 2000 years. Then the Lafourche course was gradually abandoned in favor of the present Mississippi channel. A diversion of the main channel near Donaldsonville about 1500 years ago directed increasing amounts of sediment eastward, resulting in the Plaquemines-Modern delta complex.

This dual nature of the deltaic sequence is reflected by the present-day landscape. The area displays two major subsystems. These are: 1) the abandoned delta complex of Bayou Lafourche, the Terrebonne region, and 2) the basin confined between the Lafourche complex and the active channel-levee system of the modern Mississippi, the Barataria region. Both systems include an arcuate chain of barrier islands along their Gulfward margins.

The Terrebonne Subsystem

The deltaic landscape of the Terrebonne region is dominated by a maze of natural levees that flank the abandoned distributary channels of the Lafourche-Mississippi. The ridges and channels fan out from the cities of Thibodaux and Houma, where the main Lafourche channel branched

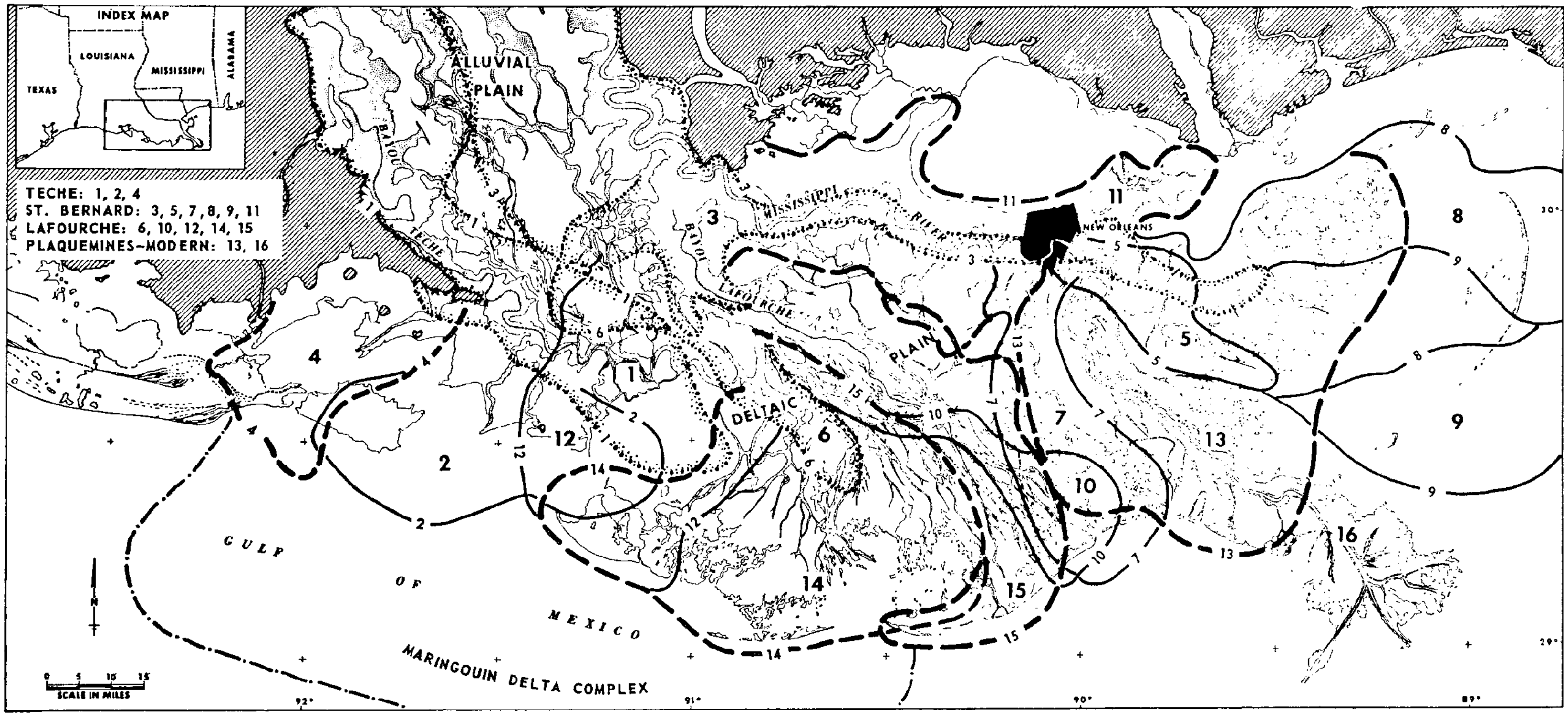


Figure 3-1. Delta lobes formed by the Mississippi River during the past 6,000 years. (After Frazier, 1967).

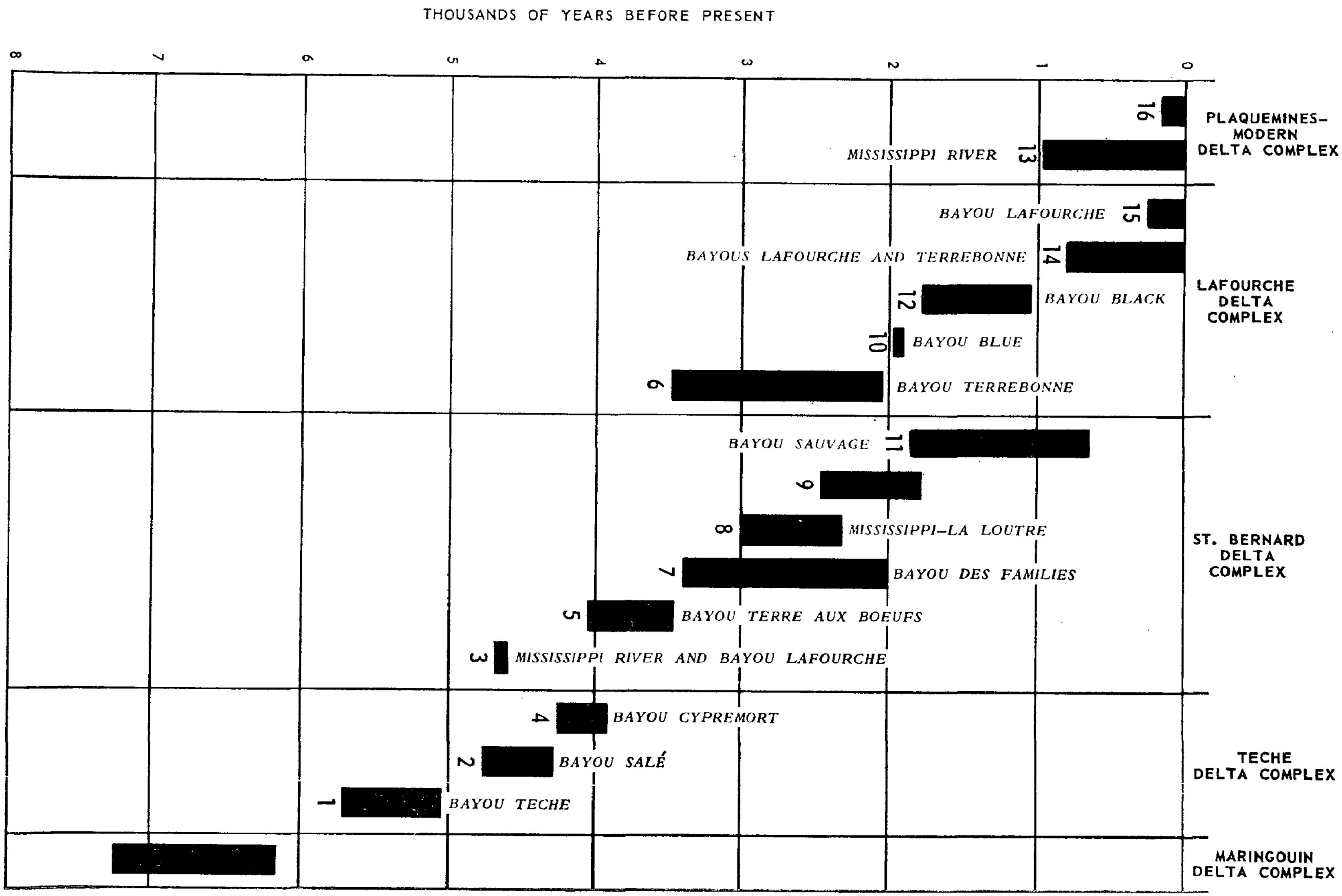


Figure 3-2. Chronology of delta lobes as determined by radiocarbon dating of deltaic plain peat deposits. (After Frazier, 1967).

into smaller distributaries. These locations were equivalent to the present day Head of Passes of the Mississippi. Bayou Lafourche represents the youngest of the major distributaries active at one time. Earlier building stages of the Lafourche delta complex involved, successively, establishment of the Bayou Terrebonne course and reoccupation of the Bayou Black channel, originally a distributary of the Teche delta complex.

The natural levee ridges form a skeletal framework of positive topographic elements. Established during delta progradation and further built up by sediment deposited during overbank flow, the levees are a tribute to the fact that at one time rates of deposition exceeded the combined effects of subsidence and erosion. The natural levees vary in height and width according to original size and amount of subsidence. Original size relates to one time importance of the associated channel as a distributary and the time period this channel remained active. Variation in the amount of subsidence is a function of age and a general Gulfward increase in subsidence rates due to seaward downwarping (Fisk, 1956). In general, the distributary levees attain higher elevations and greater widths upstream. Levees flanking Bayou Lafourche are the most prominent, with crest elevations of as much as 15 feet in the vicinity of Thibodaux. Though sloping gradually seaward and becoming ever narrower, they stand out as a natural corridor that traverses the full width of the coastal zone.

Lying between natural levee ridges are large interdistributary basins, occupied by extensive swamps, marshes, lakes, and bays. Inland, the basins are frequently enclosed as a result of overlapping of distributary subsystems. Toward the coast, the basins generally widen and are open in a seaward direction. Established as shallow water bodies between extending levees, these basins gradually filled as the delta prograded. Initial filling resulted mainly from an influx of inorganic fine sediments carried into the basins during overbank flow and crevassing of the flanking distributaries. Eventually, however, the basin floor was raised to the extent that colonization by marsh plants could occur. From that time on, organic accumulation became increasingly important. With subsidence continuing, this accumulation, where dominant over the introduction of inorganic sediments, resulted in development of thick peat beds. Peat beds attain large thickness, particularly in the inland basins where the progradational and aggradational sequence allows establishment of cypress-gum swamps. These swamps were able to persist until present time through a rate of peat accumulation that offset surface subsidence.

The Barataria Subsystem

The Barataria region may be considered the counterpart of the Terrebonne region. In essence, it represents an inter-levee basin, but rather than being confined between levees of the same distributary system, the Barataria basin lies between the main levees of successive delta complexes. Therefore, it should be considered on the same time and areal scale used to measure development of a delta complex.

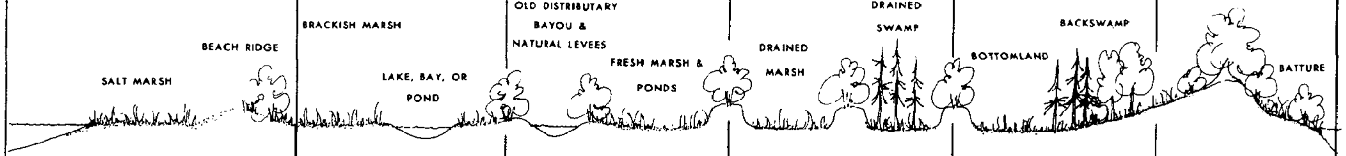
The Barataria basin shows the converging influences of both Lafourche and Modern Mississippi delta building processes. Overbank flow and crevassing from both systems have contributed to aggradation of the basin. Natural levees associated with crevasse and terminal distributaries extend into the area from both margins. Basin filling was dependent on the extent to which lateral influxes of sediment merged along the basin axis. Through most of the basin, deposition of inorganic sediments allowed a swamp and marsh succession. Greatly enhanced by accumulation of organic debris, aggradation has raised and maintained surface levels at about high tide Gulf level. The degree to which organic accumulation contributed to this is manifest in extensive peat beds that reach thicknesses of 20 feet or more in the upper basin.

Environmental Differentiation

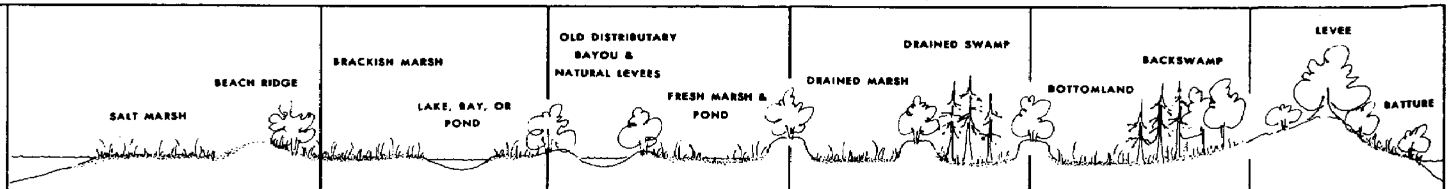
The major physiographic elements, such as natural levees and interlevee basins, provide an environmental differentiation that is reflected in the distributions of soil and vegetation types (Plates 8 and 9). Both are largely a function of elevation differences and water levels, and of topographic control over fresh water dispersion and salt water intrusion. For both soils and vegetation, two gradients can be recognized, resulting from combined affects of salinity and elevation differences. One gradient is directed from the natural levees into the basins with elevation the primary, and salinity the secondary control. A second gradient is directed from the coast inland, and primarily reflects the decrease in open water salinities in that direction. From the levees into the basins this produces a gradation from relatively well-drained to silty soils and levee forest habitats, to poorly-drained, highly organic clays and either swamp or marsh habitat, depending on salinities. Major vegetative transitions are shown in the transects of Figures 3-3 and 3-4. Detailed schematics of vegetation zones and corresponding fauna are shown in Figures 3-5 and 3-6.

Figure 3-3. Transect showing transition from natural levee oak forest to cypress-gum swamp, to fresh water marsh, (Penfound and Hathaway, 1938).

Figure 3-4. Transect showing transition from natural levee oak forest to brackish marsh through a shrub and cane zone, (Penfound and Hathaway, 1938).



TYPICAL FLORA	SALT MARSH / BEACH RIDGE	BRACKISH MARSH / LAKE, BAY, OR POND	OLD DISTRIBUTARY BAYOU & NATURAL LEVEES / FRESH MARSH & PONDS	DRAINED MARSH / DRAINED SWAMP	BOTTOMLAND / BACKSWAMP	LEVEE / BATTURE
TREES	black mangrove live oak toothache hackberry hawthorns oppanax		redbay waterelm cypress swamp privet water locust redgum overcup oak bitter pecan persimmon hackberry cherrybark oak willow thickets swamp maple pumpkin ash cypress hackberry	ON MIDDENS/OLD BEACHES willow pecan oak hackberry fig iron tree dogwood ON SPOIL BANKS tallow live oak toothache hackberry hawthorns oppanax scrub cypress oak tallow swamp red maple water ash green ash willow water oak	cypress tupelo gum swamp red maple water ash pumpkin ash sweetbay overcup oak hawthorn bitter pecan green ash willow water oak hickory nuttall oak water oak green ash cottonwood sweetgum redgum cherrybark oak cow oak shumard oak honey locust American elm	cottonwood sweetgum water oak willow American sycamore redgum hackberry honeylocust water locust silver maple
SHRUBS	marsh elder baccharis sea-oxeye salt wort marsh elder baccharis lantana	marsh elder sea oxeye baccharis swamp loosestrife slim aster salt wort buttonbush salt wort glass wort fetterbush slim aster	marsh elder baccharis elderberry lantana snowbell buttonbush marsh elder wax myrtle sea oxeye elderberry rattlebox baccharis	marsh elder baccharis elderberry ON MIDDENS/OLD BEACHES blueberry palmetto cane cacti dewberry wax myrtle baccharis buttonbush fetterbush	palmetto snowbell baccharis palmetto elderberry marsh elder virginia willow buttonbush	buttonbush wax myrtle palmetto baccharis elderberry lantana privet
VINES		wild cowpea dodder fern morning glory	poison ivy rattan vine vigna repens wild cowpea	poison ivy rattan vine poison ivy rattan vine	rattan vine poison ivy grape greenbrier	poison ivy grape rattan vine smilax greenbrier
HERBS	batis saltgrass black rush glasswort oyster grass sand rush couch grass three-corner grass sea-side goldenrod	wiregrass couch grass cattail sand rush oyster grass black rush dwarf spikerush three-corner grass leafy three-square grass waterhyssop cyperus walter's millet paspalum roseau cattail reed cane royal fern camphorweed roseau pickerel weed arrowhead water millet giant bulrush paille fine	delta potato rose mallow cattail reed cane cut grass roseau arrowhead pickerel weed water millet giant bulrush paille fine cord grass waterhyssop cyperus walter's millet paspalum roseau primrose willow royal fern water fern triangle sedge spike sedge alligator weed duckweed spikerush water pennywort paille fine bulltongue	volunteer grasses on ridges: bermuda dallis johnson bluestem vasey carpet st. augustine common reed cut grass cattail roseau cane alligator weed sawgrass paille fine coastal bermuda	feather grass cattail couch grass paille fine alligator weed roseau passle weed sawgrass rose-mallow delta potato pickerel weed cut grass	switch cane others
AQUATICS		widgeon grass	white water lily water hyacinth water hyacinth white water lily spider lily american lotus		water hyacinth white water lily	
ALGAE	benthic algae phytoplankton	benthic algae phytoplankton	benthic algae phytoplankton	benthic algae phytoplankton	benthic algae phytoplankton	benthic algae phytoplankton



TYPICAL FAUNA	SALT MARSH	BEACH RIDGE	BRACKISH MARSH	LAKE, BAY, OR POND	OLD DISTRIBUTARY BAYOU & NATURAL LEVEES	FRESH MARSH & POND	DRAINED MARSH	DRAINED SWAMP	BOTTOMLAND	BACKSWAMP	LEVEE / BATTURE
MICRO-ORGANISMS	bacteria, fungi meiofauna polychaetes amphipods protoza	bacteria meiofauna protoza	bacteria meiofauna polychaetes	bacteria zooplankton polychaetes meiofauna	bacteria zooplankton meiofauna	bacteria zooplankton meiofauna	bacteria meiofauna	bacteria meiofauna	bacteria meiofauna oligochaetes		bacteria earthworms meiofauna
MOLLUSKS CRUSTACEANS	fiddler crabs mud crabs mussels snails	Donax (bivalve) ghost crabs * burrowing shrimp isopods	snails crabs clams shrimp mussels oysters	oyster marsh clam shrimp crabs	snails crayfish mussels clams	snails crayfish mussels clams	land snails		snails crayfish mussels clams		land snails pill bugs
AMPHIBIANS & REPTILES	salt marsh water snake		alligators	alligators	alligators turtles water snakes salamanders frogs	frogs water snakes turtles salamanders alligators	toads snakes salamanders		tree frogs bullfrogs leopard frogs water snakes		tree frogs toads salamanders snakes
FISH	killifish		killifish	bay anchovies silverside menhaden sea catfish mullet many others	minnows (gambusia) perch crapie catfish gar bass	minnows (gambusia) perch crapie catfish gar bass			minnows typical fresh water fish assemblage		
BIRDS	herons, egrets ibis rails sparrows, wrens blackbirds grackles plovers, sandpipers	shore birds * gulls * terns *	wading birds ducks sparrows rails	ducks gulls terns pelicans	ducks wading birds fieldbirds blackbirds	ducks wading birds fieldbirds blackbirds	ducks wading birds fieldbirds blackbirds	wading birds hawks	wading birds hawks	wading birds hawks	warblers vireos hawks typical terrestrial birds
MAMMALS	raccoon muskrat nutria mink otter	raccoons*	raccoon muskrat nutria mink otter	porpoise otter * mink *	raccoon muskrat nutria deer	raccoon muskrat nutria deer	raccoon deer rabbit rats-mice	raccoon deer weasel opossum rabbit skunk	raccoon deer weasel opossum rabbit skunk	bear armadillo opossum raccoon rabbit deer weasel nutria	opossum raccoon rabbit deer weasel nutria
INSECTS	ants grasshoppers mosquitoes deer flies many larvae wasps	all transients	wasp ants grasshippers mosquitoes flies gnats dragonflies water insects leafhoppers	chironomid larvae	Hymenoptera (wasps, ants)	Orthoperta (grasshoppers)	Diptera (mosquitoes, flies, gnats)		Hemiptera (water insects)	Odonata (dragonflies)	Homoptera (leafhoppers)

Figure 3-6. Schematic cross-section of fauna as related to the natural environments of the Barataria-Terrebonne area.

From the coast inland, the soil and vegetation gradients are most apparent in the basins. Here one finds a transition from salt water marshes through brackish, intermediate, and fresh water marshes, to the cypress-gum swamps of the upper basins. Both marsh and swamp soils are highly organic, but organic content tends to increase towards the fresh water environment (Chabreck, 1970).

The saline to brackish marsh, which borders on the coastal zone, is firm and solid, but brackish to fresh marshes immediately inland appear to be highly unstable, with topsoil of more than 80% organic content.

The fresh floating marsh is probably the most unstable among marshes, since, as a result of compaction and subsidence, the marsh root mat has become separated from the substrate. Separation may be as much as thirty feet. The space between the rootmat and the substrate is generally filled by organic ooze or muck. This makes the area of floating marsh highly vulnerable because marsh destruction will lead to open water bodies that are too deep for an intermediate plant succession.

In the combined Barataria-Terrebonne area, the marshes are the major vegetative cover. They occupy 63% of the area, or slightly over one million acres (Chabreck, 1972). Size of the areas occupied by vegetative types, that is, saline, brackish, intermediate, and fresh marshes, are presented in Table 3-1. On Plate 9, the floating marshes are not differentiated. However, they are extensive and cover approximately one quarter million acres of the Barataria-Terrebonne area (O'Neil, 1949). Figure 3-7 shows their distribution.

TABLE 3-1.

Plant Species Composition, Average Soil-Water, Salinity, and Acreage of Marsh Zones within the Barataria-Terrebonne Wetlands[1]

Plant Species	Marsh Zones				Total marsh
	Saline	Brackish	Intermediate	Fresh	
Bacopa monnieri (waterhyssop)			13.84		3.48
Distichlis spicata (salt grass)	10.85	21.02			7.96
Eleocharis sp. (spike rush)				15.17	3.79
Juncus roemerianus (black rush)	9.29				2.32
Panicum hemitomon (maiden cane)				41.76	10.44
Pluchea camphorata (camphorweed)			9.95		2.48
Sagittaria falcata (bulltongue)			3.13	12.50	3.90
Spartina alterniflora (oyster grass)	65.26				16.31
Spartina patens (wire grass)		54.61	38.11		23.18
Total	85.40	75.63	65.03	69.43	73.86
Average Soil/Water Salinity in ppt.	17	9	5	1	
Total Acreage in thousands of acres	328	261	58	405	1052

[1] Data derived for Hydrologic Units IV and V (Plate 9) from Chabreck, 1972. Plant species composition of marsh zones is expressed in percent frequency.

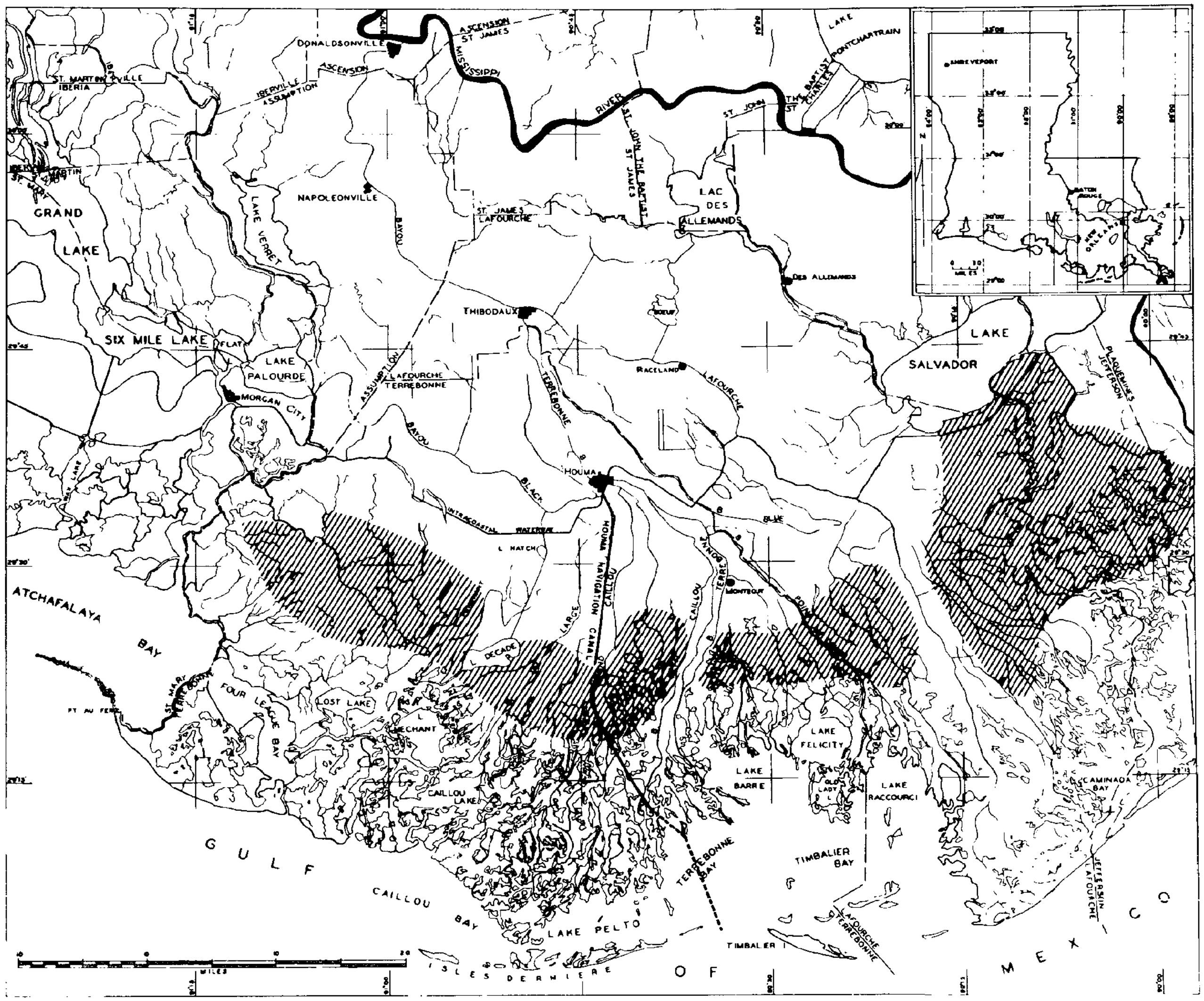


Figure 3-7. Distribution of flotant (After O'Neil, 1949).

Barrier Islands

The barrier islands are an integral part of the deltaic system. Although initial development of the islands is not fully understood, they can be placed in a general framework of delta building and abandonment (Russell, 1948; Fisk, 1955; Kwon, 1969). During active progradation of a delta lobe, fluvially transported sands are deposited in the immediate vicinity of the distributary mouths, where current velocities are reduced. These sands are subsequently redistributed along the delta margin, and depending on quantities available and the wave and current regime, they may become apparent as delta marginal beaches, spits, and beach ridge complexes. As the delta lobe is abandoned and submergence of the deltaic surface is initiated as a result of subsidence, the sand deposits tend to remain as a series of barrier beaches or barrier islands, separated from the retreating delta shoreline by a shallow sound or estuary. As subsidence continues, the barrier sediments become increasingly subject to redistribution, resulting in an inland migration of the islands. This migration is generally coupled with a loss of sediment, and consequently, with a decrease in size of the individual islands.

The chain of barrier islands fringing the Barataria-Terrebonne region relates to subsequent progradation and abandonment of at least two Lafourche-Mississippi delta lobes, and possibly to a distributary system associated with the Plaquemines-Modern complex. Two barrier chains can be identified. These are 1) the Isles Dernieres chain, which includes the Isles Dernieres proper as well as Caillou Island, Brush Island, and Casse Tete Island further to the east, and 2) the Timbalier-Grand Isle chain extending to the east and west of the massive Caminada beach ridge complex near the mouth of Bayou Lafourche, and including the Timbalier Islands, Grand Isle, and the Grand Terre Islands.

Development of the Isles Dernieres chain relates to the attenuation of a subdelta that was associated with Lafourche-Mississippi distributaries branching out from Houma; e.g., Bayou Petit Caillou and Bayou Terrebonne. The Timbalier-Grand Isle chain, as well as the associated beach ridge complex, relates to a subsequent phase of delta building and abandonment corresponding to the history of Bayou Lafourche as a major Mississippi distributary. Sequential nature of development of the two barrier arcs is apparent in the partial envelopment of the Isles Dernieres chain by the Timbalier-Grand Isle arc.

Development of the greater Terrebonne estuary as an integrated bay complex, and the concurrent migration and modification of the Isles Dernieres barrier arc, as well as the western wing of the Timbalier-Grand Isle arc are shown in Figure 3-8. The one hundred year sequence shows gradual coalescence of Terrebonne and Timbalier Bays, which were initially separated by the Bayou Terrebonne levee complex. A similar sequence can be visualized for Barataria and Caminada Bays in relation to the distributary complex of Bayou Lafourche.

Subsurface Characteristics

Of major consequence concerning development and management of the area under consideration are the characteristics of the vertical column. For instance, where a natural levee has subsided, in part or totally below the marsh surface, a firm substrate may be found at small depths. In particular, the distribution of sands in the coastal area is important. Sand bodies may provide supplementary sediment for process management or stable surfaces for necessary development.

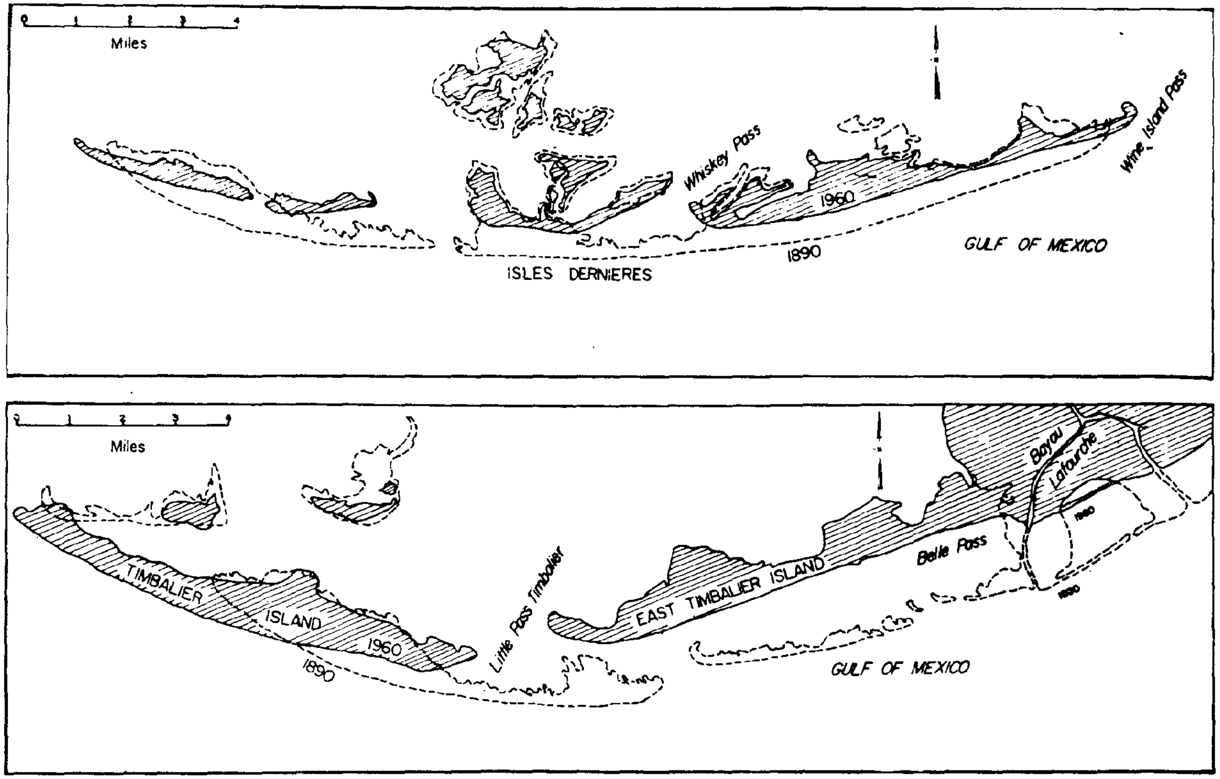


Figure 3-8. Shoreline changes of delta margin islands in the abandoned Lafourche Delta System, 1890-1960. (After Peyronnin, 1965.)

Figure 3-9 illustrates the subsurface conditions of the early Lafourche delta along a profile from Houma to Terrebonne Bay. The layer of organic matter or peat on top of the section, which constitutes highly unstable deltaic or marsh surface, is essentially continuous and gradually thickens toward the coast. On the other hand, the underlying soft organic clays increase in depth inland. Sequence of deposition in this area is not well known, but the lower peat layer probably represents the subsided marsh surface of one of the older Mississippi River subdeltas buried by a subsequent wave of alluviation as the early Lafourche delta advanced into the area.

Figure 3-10 shows a sedimentary profile in a floating marsh of Barataria Bay basin. According to the profile, a natural levee has subsided below marsh surface, and the sediments composing the natural levee, together with "soft, organic clay," appear to represent the former active flood plain surface. The upper vegetative mat floats on a marsh ooze that reaches a thickness of eleven feet. Organic content of this type of marsh is typically high, usually greater than 50 percent (Kolb and van Lopik, 1959).

Figure 3-11, after Fisk (1955), illustrates a simple depositional sequence in the area of lower Bayou Lafourche. The sandy materials are carried down to the mouths of former active distributaries in this area and distributed around the delta fronts by waves and longshore currents. The delta front sheet sands rest upon massive prodelta silty clays, and grade upward into gray and black organic-rich marsh deposits. The sheet sands occur at or near the surface around the mouths of Bayous Lafourche and Moreau, and are present at progressively greater

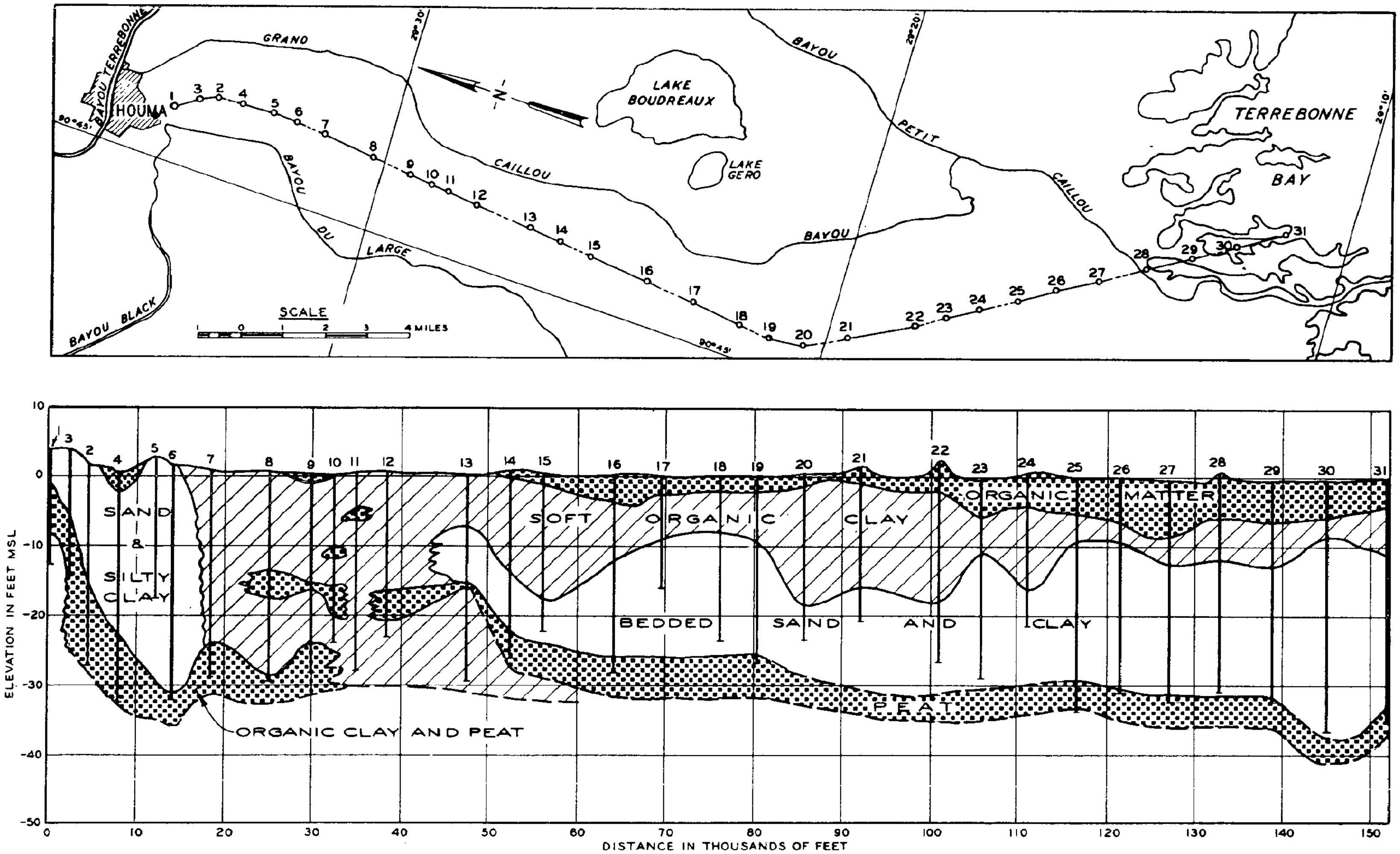


Figure 3-9. Profile showing buried marsh layer along proposed Houma Ship Channel. (After Kolb and Van Lopik, 1959).

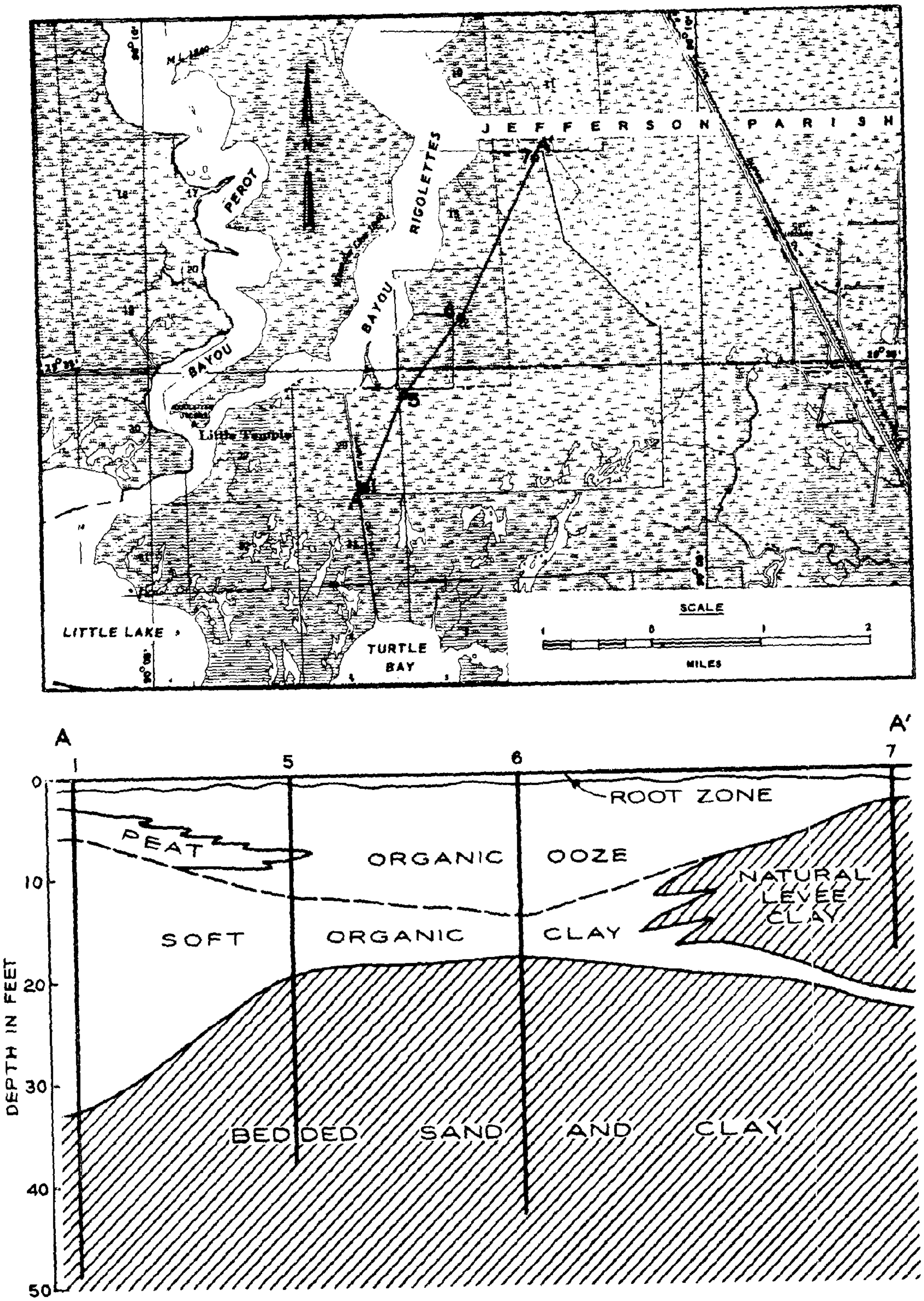


Figure 3-10. Typical section in floating marsh or flotant about 22 miles south of New Orleans. (After Kolb and Van Lopik, 1959).

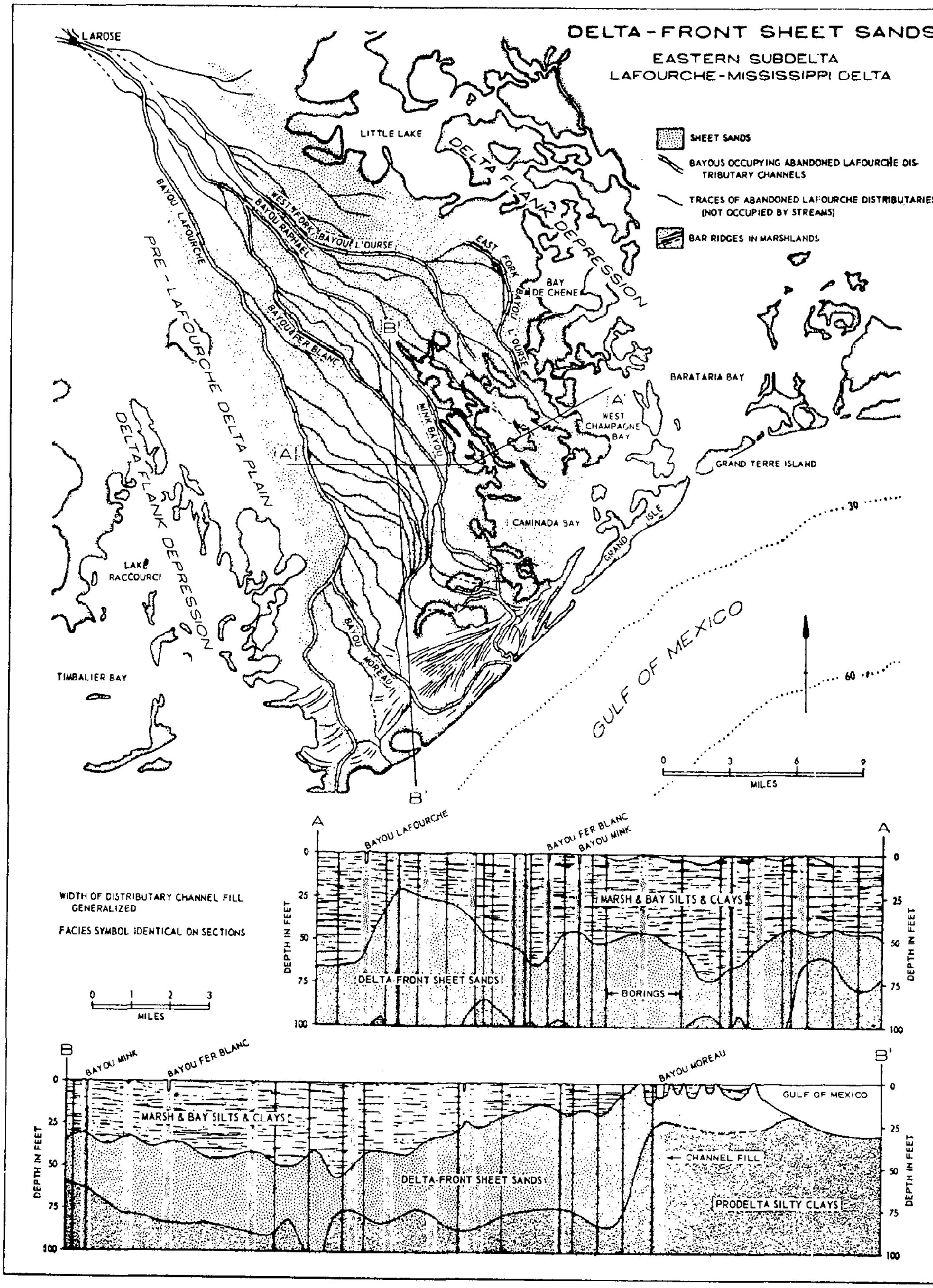


Figure 3-11. Geomorphic features and sedimentary deposits in the abandoned Lafourche Delta Complex. Black dots indicate location of oyster reefs. (After Fisk, 1955).

depths inland. These sands lie forty feet beneath the delta plain marsh near the head of the Lafourche distributary system. The thickness of marsh deposits is indicative of the amount of regional subsidence and compaction that has taken place while delta surface deposition was progressing, and subsequently, as the marsh sediments have accumulated.

The upper surface of the sheet sands at its seaward margin can be seen in the series of beach ridges in the marshes surrounding the distal ends of Bayous Lafourche and Moreau. These ridges have sunk almost to sea level, but their development was contemporaneous with the final stages of seaward lengthening of the bayou courses.

The occurrence of the sheet sands at or near the deltaic surface in the lower reach of Bayou Lafourche and increasing thickness of organic-rich marsh deposits inland explain the firmer nature of land toward the seaward margin of this abandoned delta. They also partly explain the reason why the higher rates of land loss occur inland, although actual rate of compaction and regional subsidence is greater Gulfward.

Natural Deterioration and the Delta Cycle

When examining a detailed map of the Barataria-Terrebonne region one notices immediately that conditions at present are far from those associated with an actively prograding and aggrading delta system. The sea has made inroads into both the Lafourche delta and the Barataria basin so that both function now as large estuaries. This condition represents a phase of modification associated with abandonment and bypassing of the area by the main stream of fresh water and sediment. For the Terrebonne region this condition was initiated when the Mississippi River abandoned its Lafourche course in favor of the present channel. For the Barataria region, it followed when the Plaquemine-modern complex extended rapidly seaward to the edge of the continental shelf.

In a natural setting, abandonment and bypassing of deltaic sub-systems is an inherent part of the deltaic sequence, as is the subsequent disintegration. When a delta complex is deprived of most of the previous sediment influx, seaward progradation will give way to shoreline retreat under the influence of wave action and subsidence. Marine ingression is commensurate and partial drowning of the interdistributary basins produces a hierarchy of bays. The bays are initially confined by the skeletal framework of natural levee ridges. This condition is well illustrated by the greater Terrebonne Bay and along the margins of the Barataria Basin. Both estuaries show a highly irregular shoreline representing a land-water interface whose length is many times that expected from size of the water bodies. The length of interface, together with the areal land-water ratio are major factors in determining biological productivity of the estuaries.

An important factor in the beneficial development of crenulate bay shorelines is the degree to which the shores are protected from wave erosion. Although levee and basin deposits differ in sediment composition and resistence to wave erosion, under the low energy wave regime of the present estuaries, shoreline configuration is largely a function of elevation. Subjected to subsidence, the higher levee ridges escape submergence longer than the low surface of the interdistributary basins. Hence, development of the estuary as an integrated bay system is allowed for as long as levee ridges extending into the estuary can resist wave erosion; a condition that related to the presence of a barrier island chain sheltering the estuaries from the higher energy wave regime of the open Gulf.

There are three major natural processes that account for wetland deterioration: 1) drowning of the marsh due to subsidence, 2) shore erosion of lakes and bays, and 3) new marsh opening. These may occur individually or concurrently.

Subsidence

The areas of maximum land loss are the areas of maximum subsidence, a fact that is documented in the historic maps of coastal Louisiana. When the filling in of the interdistributary basins by mineral or organic sediments and vegetation growth keeps up with subsidence, for instance, as in the fresh floating marsh, the marshes can overcome subsidence. However, there many examples of areas where subsidence occurs too rapidly for the marshes to sustain themselves. According to Figure 3-12, there was the remnant of early Lafourche delta in the present area of Terrebonne Bay until after the middle of the last century. Since then, the delta lobe disappeared completely, with only relict channels traceable in the rim of the upper bay.

Deterioration or subsidence of this subdelta lobe has possibly undergone two stages of acceleration and deceleration. It is believed that land deterioration was very slow during the gradual reduction of water discharge through the subdelta system, and for some time after the abandonment. The rate of subsidence could be constant throughout the time, but before massive delta deterioration was initiated, land loss should have been restrained by the protection of high and firm saline marshes and sandy foundations around the delta front. When the

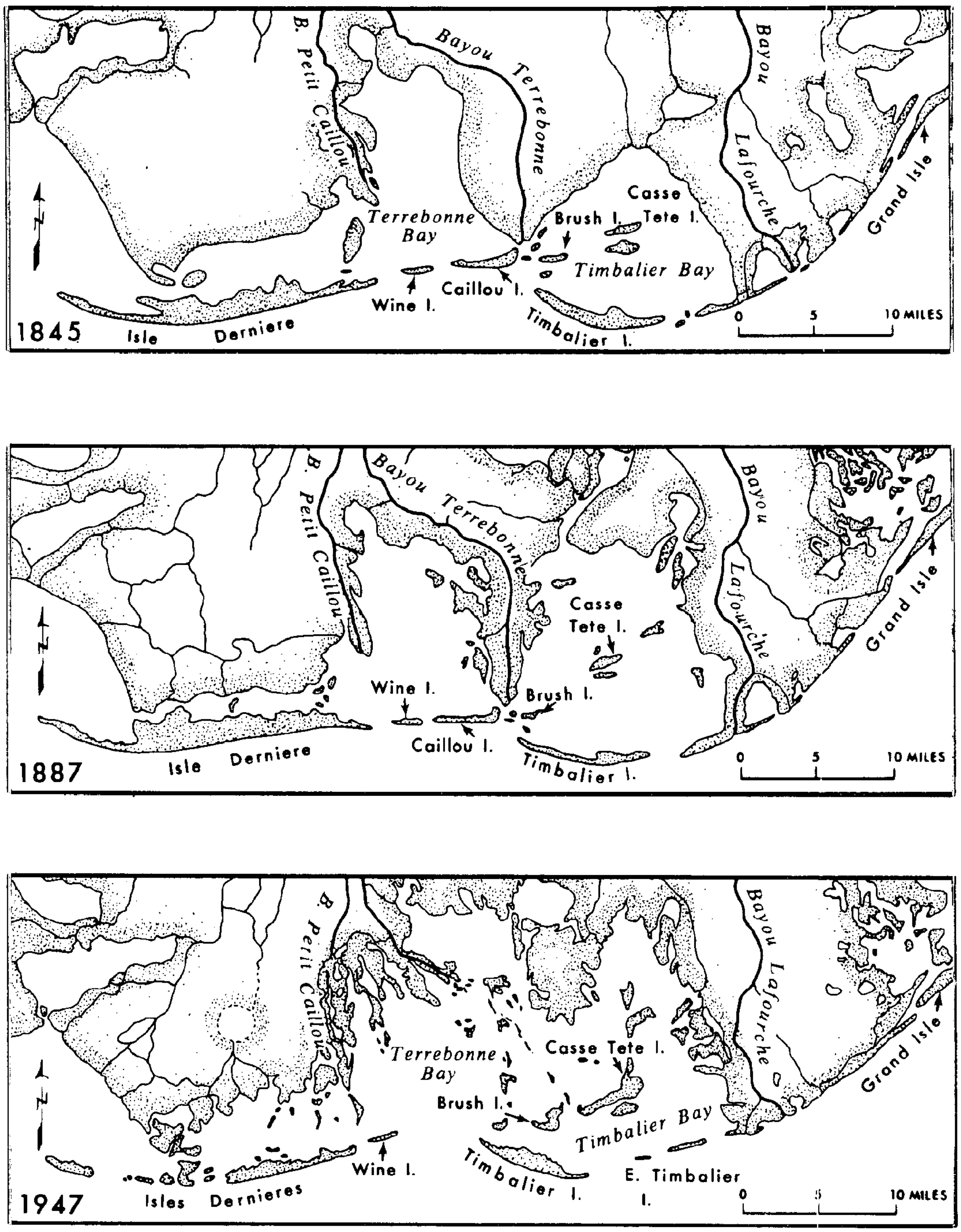
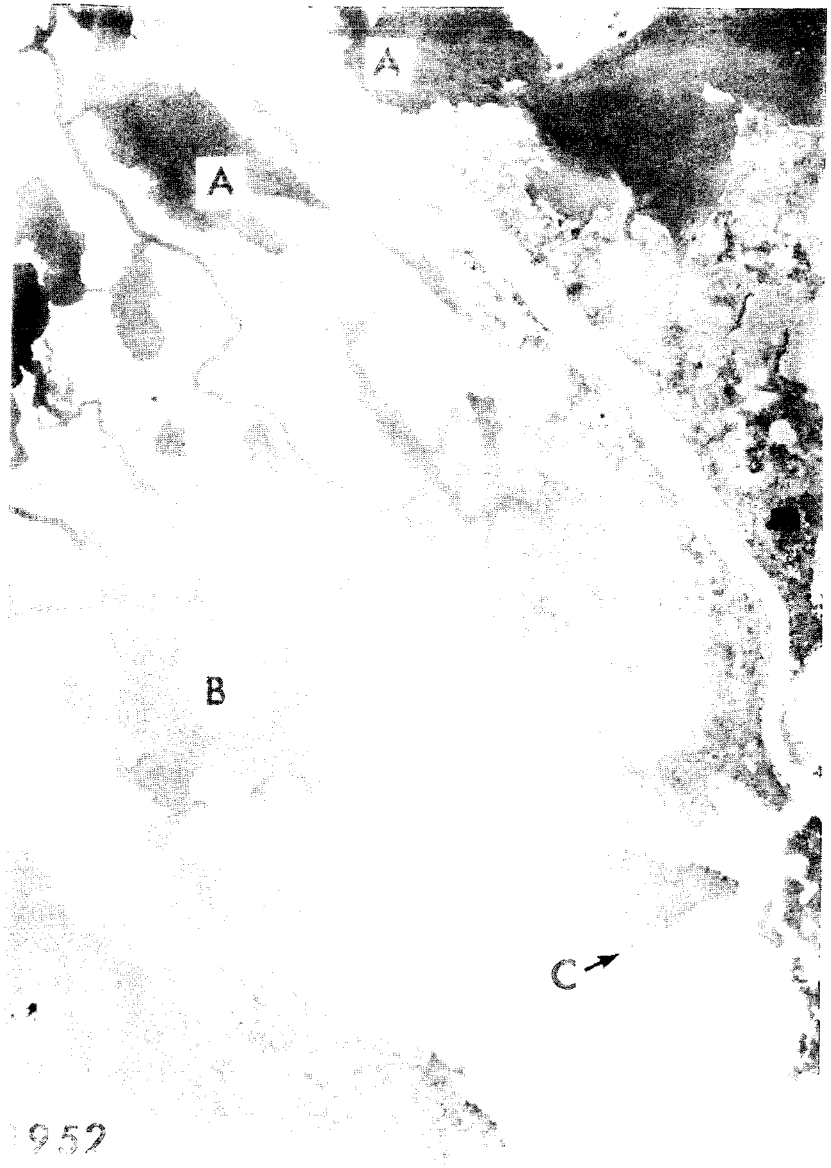


Figure 3-12. Shoreline changes in the abandoned Lafourche Delta complex, 1845-1947. (After Kwon, 1969).

protective barrier was removed by further subsidence and coastal retreat, the low and vulnerable inland marshes with high organic soil content were exposed to high waves from the Gulf of Mexico and intrusion of salt water. If the protective barrier did not disappear, but continued to exist in the form of barrier islands like Isles Dernieres and Timbalier Island, submergence of the marsh surface was initiated in low places behind the barrier, but the net effect of Gulf water intrusion should be the same. A slight subsidence could drown extensively the low inland marshes, if vegetation growth cannot keep up with the subsidence. It should be noted that the vegetation that maintains the floating marshes consists predominantly of fresh water species. In the above manner, marsh or delta deterioration may reach a stage of acceleration. However, when the encroachment of the bay reached the present upper Terrebonne Bay, the deterioration decelerated. Land loss calcualtions show a very low rate of loss in this area, much lower than the surrounding areas.

Levee flank depressions (Russell, 1936) are sites of rapid subsidence and opening-up of marshes. These depressions develop just outside of the natural levee backslope along the main river channel. They originate because natural levees composed of silty materials are more dense than the surrounding marsh, and their weight tends to compact sediments beneath them. This causes the levee to subside faster than the marsh. The depressions created in a sag formed by the weight of the natural levees become the sites of elongate lakes parallel to and just marshward of the crest of the controlling levee. Bay Lucien provides an excellent example of a levee flank depression lake along Terrebonne Bayou (Fig. 3-13). These lakes expand at the expense of the

Figure 3-13. Marsh deterioration as a result of subsidence. The bays and lakes in the photographs have highly irregular shoreline patterns which is one of the characteristics in areas where subsidence is dominant over wave erosion as a cause of marsh break-up. Bay Lucien and Bay la Fleur are examples of levee-flank depression lakes (A). The depressions originate where subsidence of the natural levee is more rapid than subsidence of the marsh in the adjacent interlevee basin (B). Retreat of the shore line from 1952 to 1969 is readily apparent at point C. A decreased land-water ratio has further resulted from the dredging of additional canals and a widening of Terrebonne Bayou.


A
A
B
C
952


A
A
B
C
Bayou
Bay
Lucien
de
Terrebonne
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Bayou
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l'Ouest
Bayou
Jack
Lucien
Bayou
Bay
Negresse
Contraband
BAY
LAKE
LAGRAISSE
1969

natural levee and marsh, and in an advanced stage, the lakes join with those of interdistributary basins. This process throws light on the development of numerous lakes and encroachment of bays toward the backslope of natural levees of the Mississippi River below New Orleans.

The linear lakes between beach ridges around the mouth of Bayou Lafourche directly result from subsidence (Fig. 3-14). In all cases, the lakes or bayous overwhelmingly dominated by subsidence have slightly irregular outlines. Marshes drown below water level before wave action starts to smooth the shores. Irregular outlines reflect local conditions of soils, vegetation, etc.

Marsh Opening

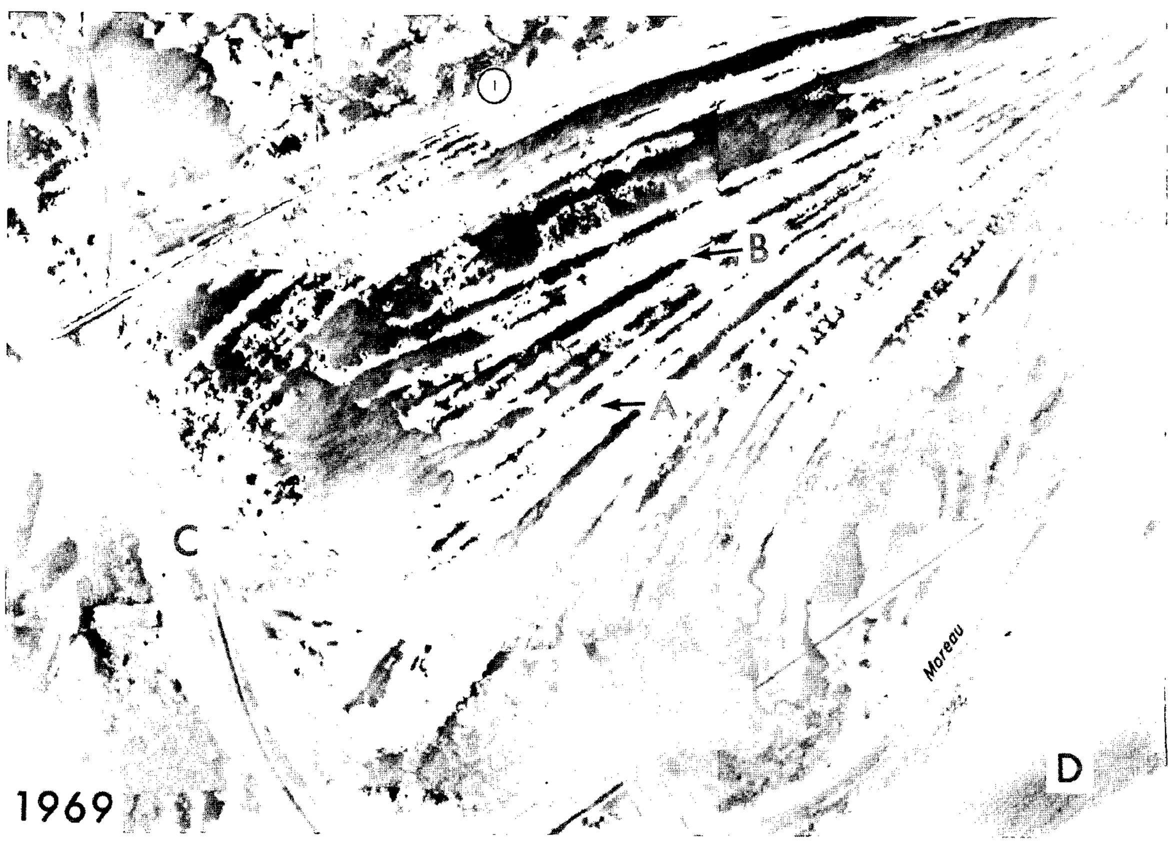
Frequently, drastic land loss occurs through marsh openings which are not directly related to subsidence. Such marsh deterioration happens as a result of 1) marsh fires, 2) animal eat-outs, and 3) storms. Depth of water in such openings may be only slightly more than one foot and the bottoms are often covered with fine ooze that overlies the original peat or organic clays of the underlying marsh (Kolb and van Lopik, 1959).

Marsh fires often happen during dry seasons. They sometimes occur naturally, but are usually deliberately set as an accepted form of marsh management. However, in extremely dry periods, when the water table drops significantly below the marsh surface, the fires may burn into the peat layer and thus create small lakes.

An eat-out describes a condition that occurs in the marshes when muskrats or nutria become overpopulated and eat all of the stalks and leaves of the marsh plants, and then burrow down to the root system which

Figure 3-14. Linear lakes between beach ridges near the mouth of Bayou Lafourche. The photographs show an alternation of sandy ridges (A) and swales (B) that are occupied by linear lakes. The beach ridge complex formed during the last stage of the Lafourche-Mississippi delta development. That is, after diversion of the Mississippi River from the Lafourche (C) to its present course had taken place. The swales were transformed into lakes as a result of subsidence. Though continuing, subsidence did not yield an appreciable expansion of the lakes during the 17 year period separating the two photographs. Increased water area is mainly a result of borrow excavation. On the other hand shoreline retreat along the Gulf of Mexico (D) is noticable.


B
A
C
D
1952


1
B
A
C
Moreau
D
1969

binds the organic soils together (O'Neil, 1949). Thus, the peaty floor is broken to a depth of as much as 20 inches, and a mucky, rotten condition is created. Once the binding root mat is destroyed, flooding during the next high water period may create a lake.

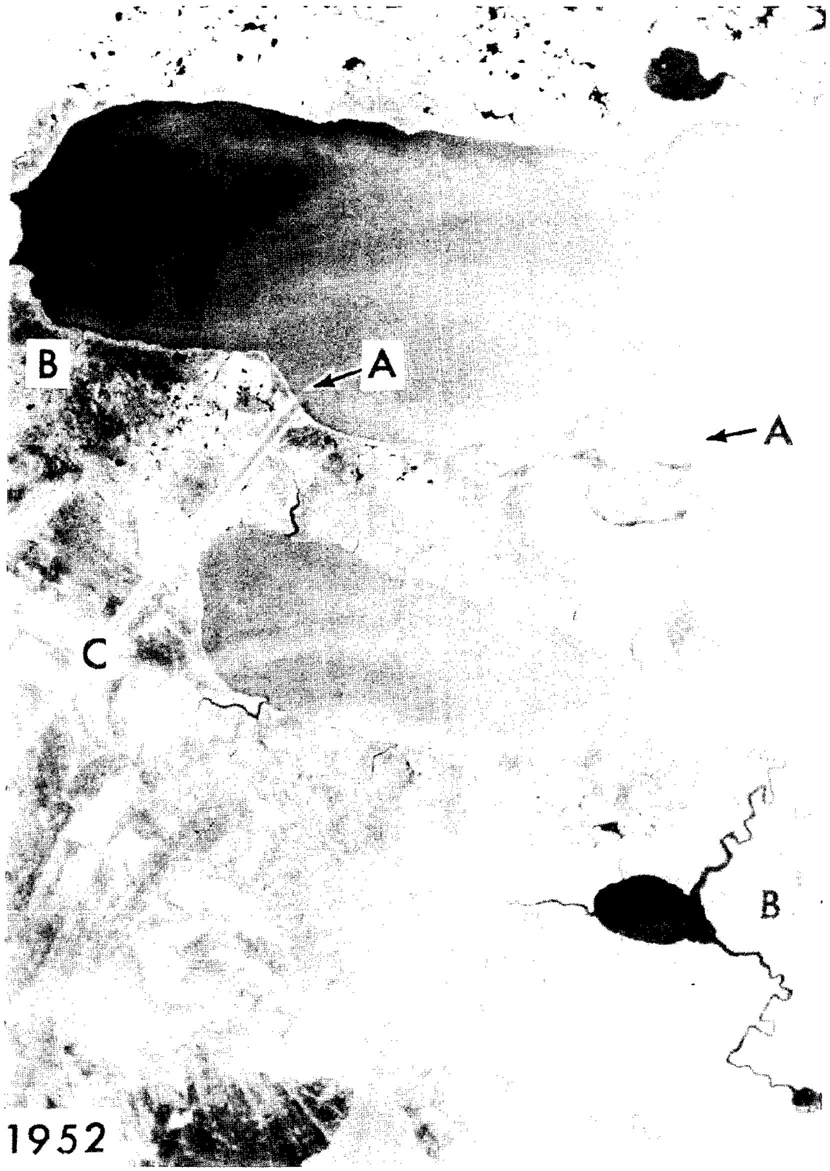
Storm tides are known to be very effective in creating new marsh openings. When water with salinities above 50 percent sea water is carried into the fresh and brackish marshes and fails to runoff rapidly, a rotting-out of the vegetation occurs resulting in large scalds or areas denuded of vegetation (Treadwell, 1955). If this takes place in fresh floating marshes, the vegetation can be so completely destroyed that permanent open ponds and lakes will form.

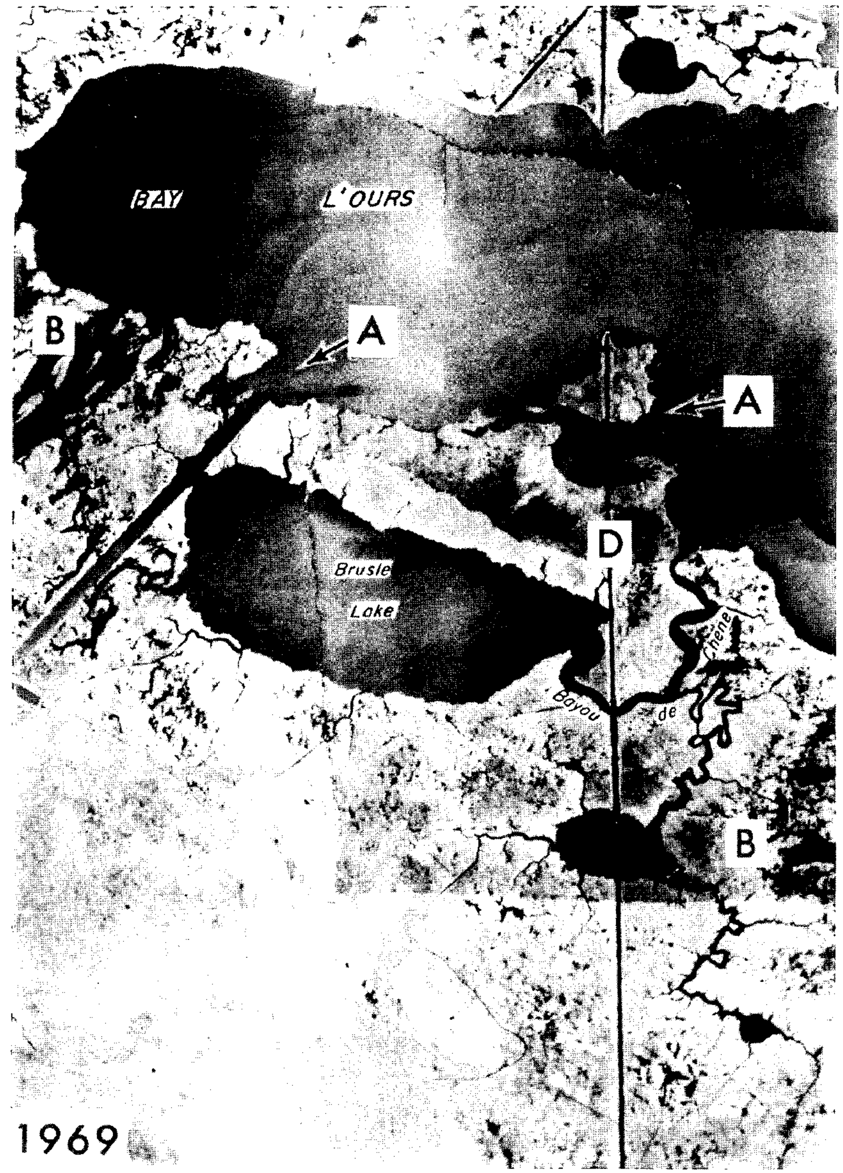
According to comparison of air photos taken at different periods, the above three processes appear to be mainly responsible for widespread openings in some areas, but the areal extent and relative frequency of each occurrence are not known at this time. Figure 3-15 illustrates the development of new marsh openings over a 20-year period.

Lakeshore Erosion

Subsidence drowns the marshes, but shore erosion along lakes and bays also contributes appreciably to marsh loss. Where subsidence rates are high, the outlines of lakes are very irregular, but where the expansion of lakes is the product of lakeshore erosion by waves, the overall outline becomes very smooth. Numerous oval or rounded lakes in the coastal marshland of Louisiana belong to the latter category. Their sizes vary greatly, ranging from tens of feet to more than 10 miles in diameter. Good examples are provided by Wilkinson Bay Chien in the Barataria Basin (Fig. 3-16). Treadwell (1955) attributes the initiation of most of these lakes to marsh fires, animal eat-outs, and storms. He

Figure 3-15. Lake shore retreat and opening up of floating marsh, Barataria Basin. Marsh deterioration appears to be serious in this area of Bay L'Ours. Shore retreat is considerable and readily apparent at locations indicated by A. The marshes are of the floating type with deterioration resulting in numerous small ponds (B) which eventually will merge into larger lakes. The 1952 photographs shows signs of extensive marsh burning, a practice related to trapping. C and D indicate pipeline canals.


B
A
A
C
B
1952


BAY
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Lake
Bayou
de
Chene
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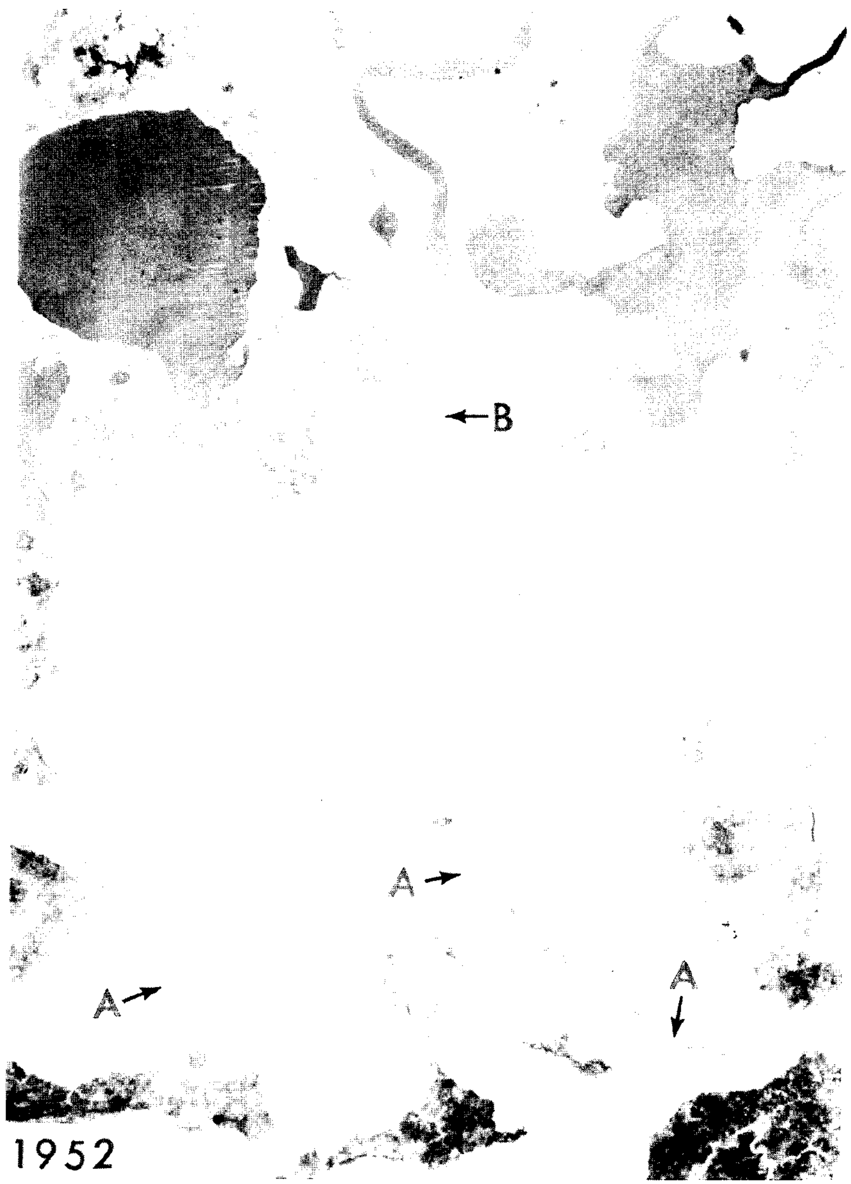
1969

Figure 3-16. Shoreline retreat along round lakes, Barataria Basin. The photographs show a series of circular shaped lakes along the northern margin of Barataria Bay. Close comparison of the two photographs reveals a small but overall retreat of the lake shore lines. Erosion is most apparent at the locations marked by A. B marks a navigation canal which has widened considerably over the 18 year period separating the photographs.


B
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A
1952


UPPER
WILKINSON
BAY
WILKINSON
BAY
Bayou
Wilkinson
B
BAY
CHENE
FLEUR
A
A
A
Wilkinson
Bayou
1969

states that in their initial stage this type of lake is of variable shape, but over most of the fairly firm marsh initial ponds tend to be rounded or oval. In areas of low, soft marsh, small ponds have irregular outlines. Regardless of the initial lake form, continued erosion of lake shores tends to round their outlines.

In addition to hurricanes, Treadwell (1955) places emphasis on wind direction distribution throughout the year. No dominant prevailing wind direction exists in coastal Louisiana. Southeasterly winds prevail in spring, northeasterly in winter, and southwesterly in summer. It is suggested that the wave erosion occurring during average years tends to develop lakes with rounded outlines.

The size of small lakes increases slowly at first, but then grows rapidly as wind fetch increases. If a lake continues to enlarge, it eventually merges with other lakes. The merger of lakes of various sizes results in large lakes whose shores are scalloped or arcuate. Through the above facts, it can be generally stated that the rounded form of lake is indicative of the firm and stable condition of the marsh such a lake is seated on, while the irregular form is suggestive of the unstable condition.

Hurricanes can be identified as a direct cause for lakeshore erosion (Russell, 1936) and marsh breakup. Observations in southwestern Louisiana following Hurricane Audrey indicate increases in marsh openings or open water areas within the marsh by as much as 100 to 150 percent (Harris and Chabreck, 1958). This type of destruction appears largely to be the result of high velocity currents generated during seaward return of floodwaters following inundation by the storm surge (Wright *et al.*, 1970).

Most vulnerable to the high velocity water movement is the cane vegetation, such as *Spartina alterniflora* and *Spartina patens*. Related to their growing cycle, density of the canes is largest during the late summer when dead culms are still present in addition to the new growth of the preceding spring. As a result, the cane forms a major obstruction to flow. In exposed conditions, the root mat may be torn from the soft substrate and large clumps of vegetation removed.

In addition to the mechanical action, hurricane surge may contribute to marsh deterioration through prolonged inundation. Apparently, many species of cane cannot tolerate total submergence for long intervals and will die under such conditions (Chamberlain, 1959). Inundation frequently is prolonged as water is retained by spoil banks that accompany canals in the marsh area.

The seriousness of hurricane effects is further compounded by the frequency with which hurricanes and tropical storms occur and the extent of associated flooding. An occurrence interval of approximately two years can be shown for the passage of hurricanes or tropical storms through the Barataria-Terrebonne region (Hope and Neuman, 1971). Plate 11 shows the area inundated during the passage of Hurricane Betsy in 1965. Water levels were raised as far as 25 miles inland from the coast, attaining a value of as much as 2.8 feet even in the des Allemands area. Figure 3-17 illustrates the flooding associated with passage of Hurricane Hilda in October, 1964. Central pressure at the time of landfall was approximately 28 inches (U. S. Army Corps of Engineers,

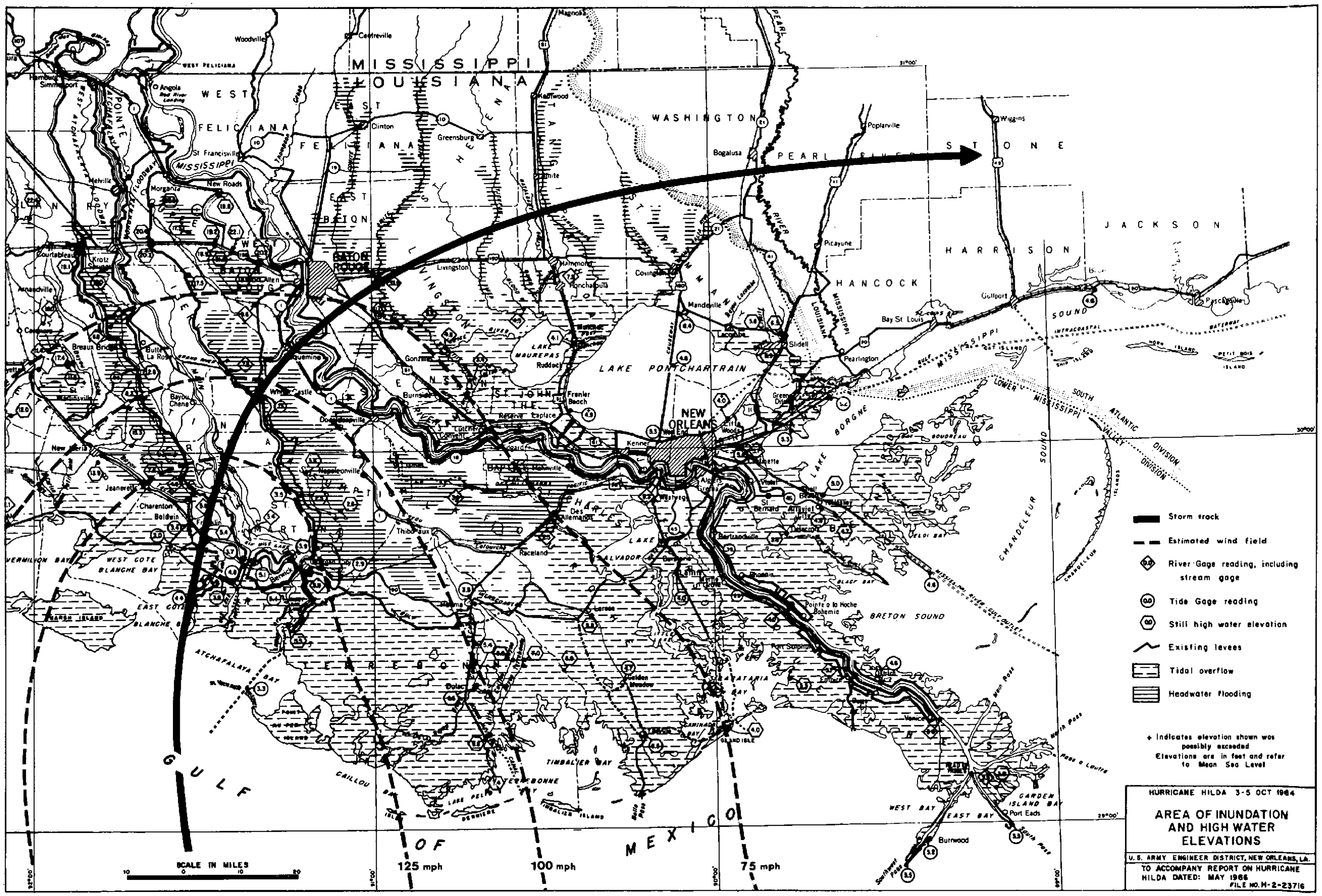


Figure 3-17. Flooding associated with the passage of Hurricane Hilda, October, 1964.

1966). Although the hurricane eye passed slightly to the east of the Terrebonne area, related to the counterclockwise circulation, the impact of the accompanying storm surge was felt to the largest extent in the Terrebonne area. Water levels along the central Terrebonne coast were raised nearly 8 feet above normal, producing extensive flooding. Accompanying the passage of the hurricane was a heavy rainfall. Total precipitation in the Terrebonne area ranged from 2.4 to 7.0 inches for the period of October 3-5. Combined with the raised tidal levels along the coast, this resulted in additional flooding of inland areas from headwater overflow. As shown by Figure 3-17, nearly the entire Barataria-Terrebonne area was inundated. The only exceptions were the higher natural levees along the upper part of Bayou Lafourche and its distributaries near Houma, and areas along the Mississippi River north of New Orleans. Embanked areas along the lower Mississippi River also escaped inundation. Flooding by tidal waters was clearly the most extensive, reaching inland from the coast as far as Raceland and New Orleans (Figure 3-17).

Fresh-Salt Water Mixing

Directly related to morphologic changes is the development of a broad fresh-salt water mixing zone (Figure 3-18). In the absence of human interference, fresh water is introduced periodically into the estuaries as a result of overbank flow of the fringing Mississippi trunk channel and its distributaries. This influx is augmented by precipitation surpluses. As a result of the large storage capacity of the upper estuary, related to the marsh-swamp environment and the numerous lakes,

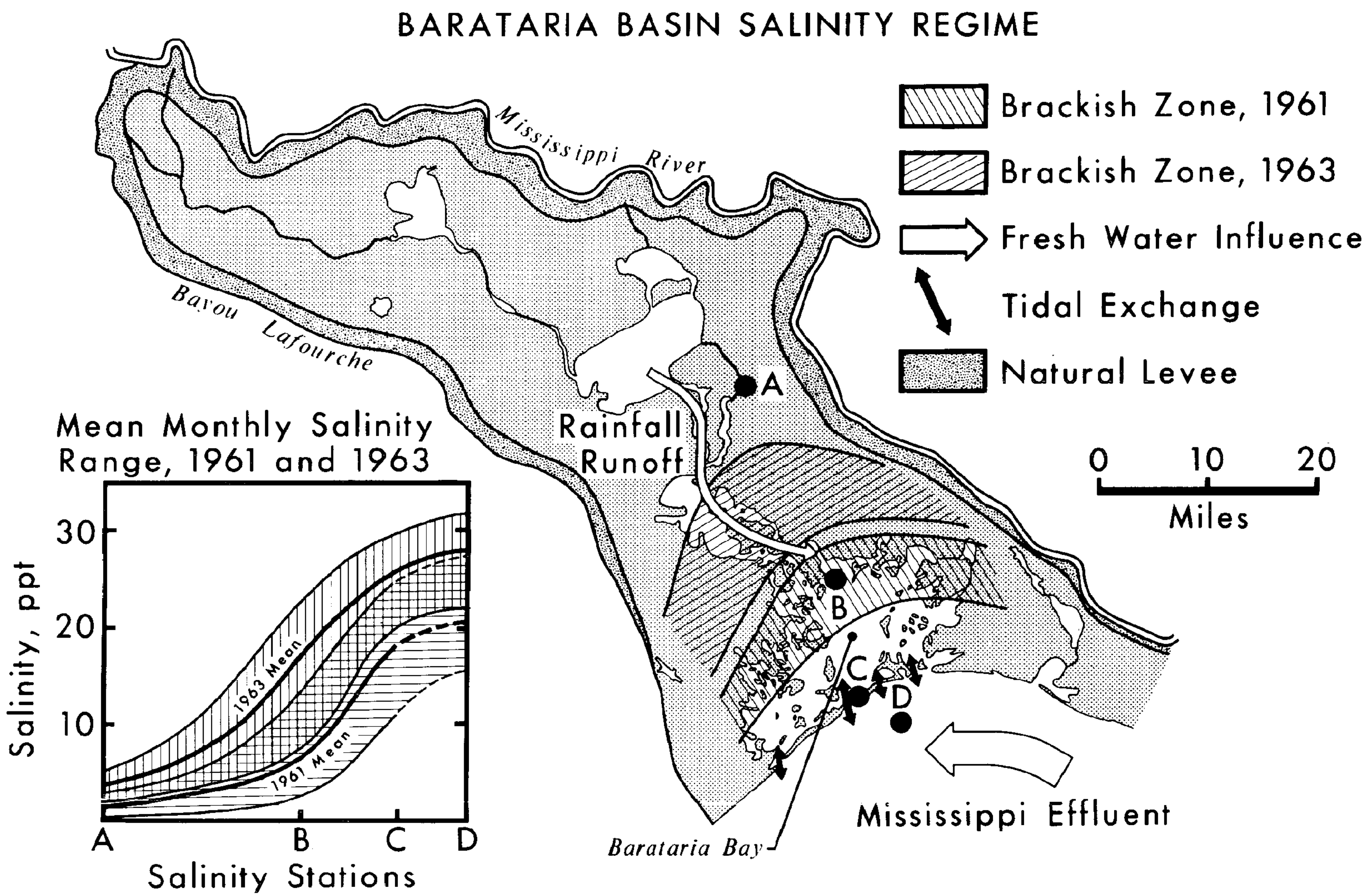


Figure 3-18. Fresh-salt water mixing zone in the Barataria-des Allemands estuary system. Primary fresh water input consists of locally derived runoff from catchment area bounded by crests of natural levee ridges along the Mississippi River and Bayou Lafourche. Tidal exchange is controlled by size of passes between barrier islands. The position of the brackish zone is contrasted between an exceptionally wet (1961) and an exceptionally dry (1963) year.

and the characteristically sinuous nature of the drainage network, fresh water is released seaward in a gradual manner. This gradual dispersal tends to distribute fresh water surpluses over extended periods, thereby reducing periods of fresh water shortage which lead to increasing salinities.

Salt water influx in the lower estuaries is a function of a large number of variables, in particular, tidal range, seasonal wind patterns, shape and size of the estuarine tidal prism, and size and number of the tidal passes between barrier islands. An additional variable is the salinity of the incoming water which changes as a function of Mississippi River discharge and offshore circulation. Limited depth of the bays appears to be prohibitive to the development of a salt wedge and well-defined vertical stratification of the water column. Mixing, as a result, occurs predominantly in a lateral direction. Together with the gradual dispersion of fresh water, this enhances development of a wide mixing zone characterized by low salinity gradients. Consequently, optimum biological habitats, in terms of salinity ranges, extend over wide areas. This is probably most apparent in the wide belts of salt, brackish, and fresh water marshes that occur in inland direction, but the same can be said for a large number of marine organisms. This aspect translates into a high biological productivity.

The Delta Cycle

The natural deterioration of the Lafourche deltaic complex and lower Barataria Basin has resulted in almost ideal estuarine conditions (Figure 3-19). The broad salt water-fresh water mixing zone, highly

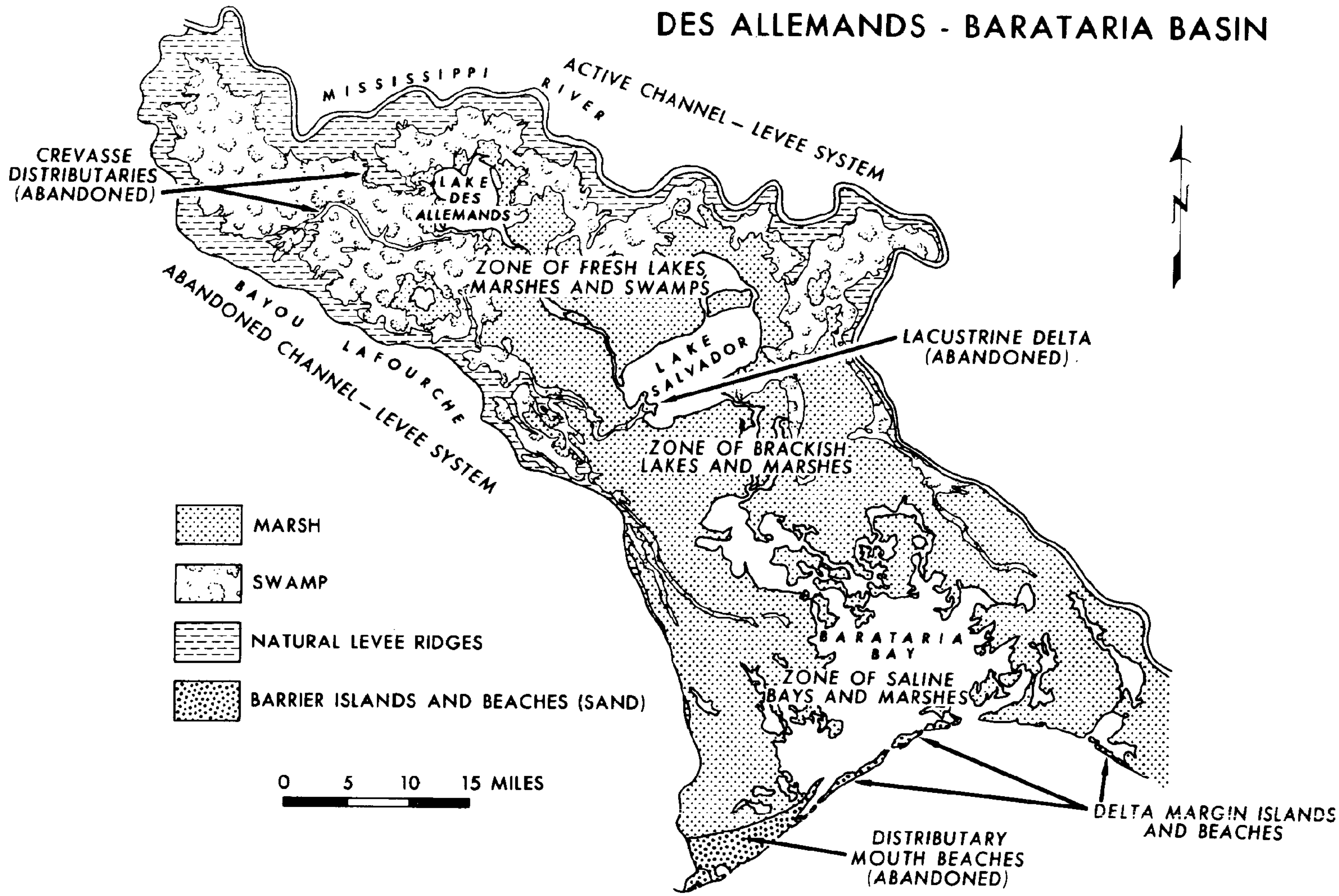


Figure 3-19. Distribution of major environments in the des Allemands-Barataria estuary system.

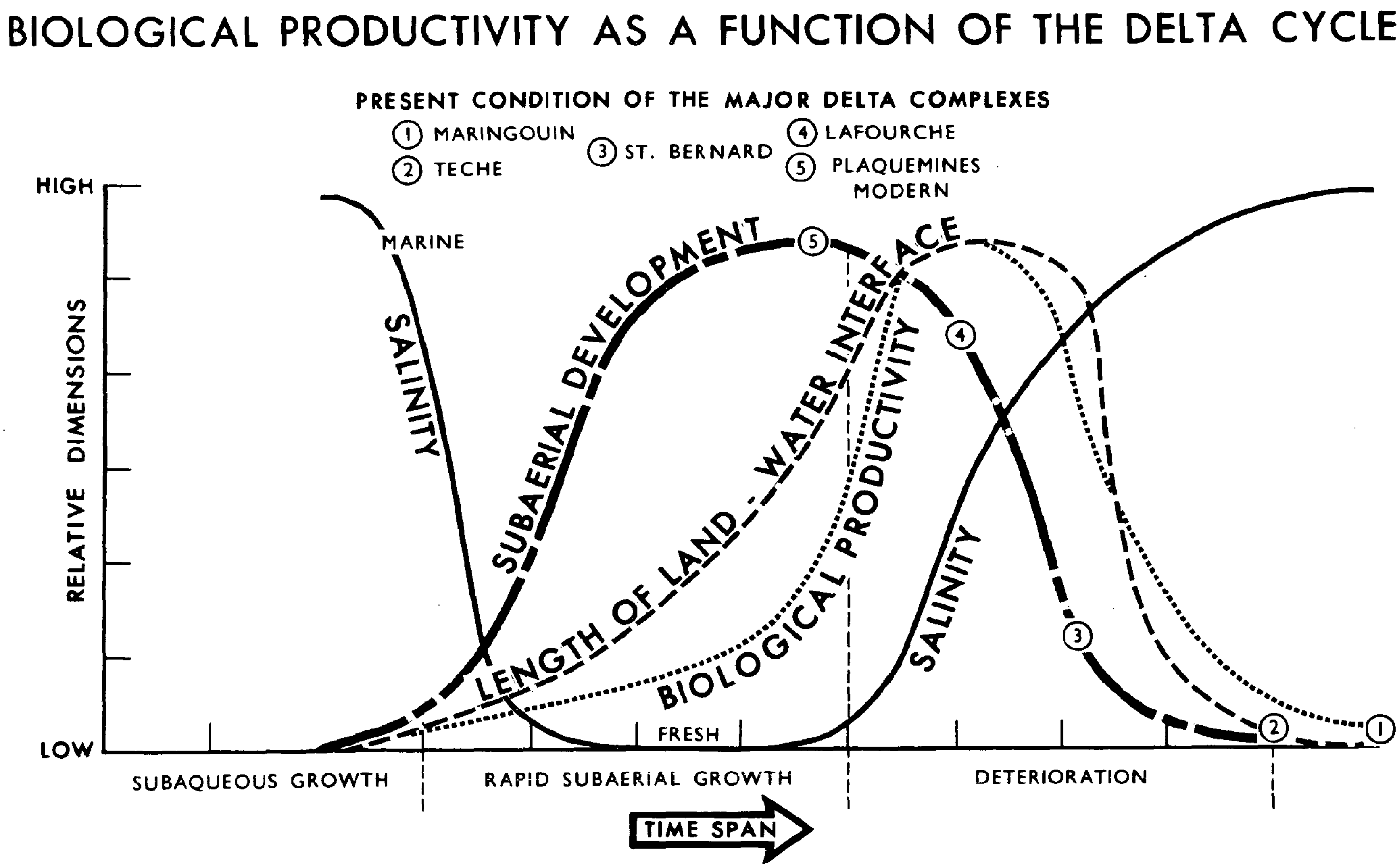


Figure 3-20. Relationship between biological productivity and the delta cycle. Ideal conditions for estuarine organisms occur during early stages of deltaic deterioration.

irregular shoreline with extensive land-water interface, broad, shallow lakes and bays, extensive fringing swamps and marshes, and protective barrier islands associated with the early stages of delta lobe deterioration result in an estuarine situation that is ideally suited for many important species of marine organisms.

Figure 3-20 illustrates the relationships between the principal variables controlling biological productivity in the Louisiana coastal zone and the deltaic cycle. It can be demonstrated that biological productivity along any major segment of the Louisiana coast between Chenier au Tigre and the Chandeleur Islands is to a large extent a function of the delta cycle. The better combinations of the principal variables and proportion and areas of various habitats occur during early stages of deterioration. Such conditions presently exist in the study area.

It should be recognized that a number of processes that have contributed to creating an optimum estuarine environment continue to operate. This means that subsidence and erosion will propagate further disintegration of the marsh surface, as is well illustrated by the Breton-Chandeleur estuary. This estuary relates to the older St. Bernard delta complex to the east of the present Mississippi River course. Here, an estuarine environment similar to that of the Barataria-Terrebonne region can be identified. However, deterioration has progressed to a much higher level, only limited protection is rendered any more by a severely eroded barrier chain, and the width of the mixing zone is relatively small. Correspondingly, biological productivity has shown a gradual decline, which indicates that progressive deterioration eventually induces a decline in productivity.

Continuing deterioration in the Barataria-Terrebonne wetlands has been documented in previous studies, most notably by changes in areal land-water ratios. Wetlands in the saline to brackish estuarine zone presently are lost at annual rates ranging from one to three acres per square mile. In part, this can be directly or indirectly attributed to human enterprises. Partly, it relates to ongoing subsidence, resulting in an increase of water area and salinity encroachment. Without doubt, it can be stated that man's activities accelerated and continue to accelerate the process of deterioration.

The effects of this are already noticeable. Examples are found in inland movement of the coastwise vegetational zonation pattern as displayed by the marshes, and an inland extension of the distribution of the oyster leases. Chabreck (1970) indicates a landward movement of two miles since the 1940's for the salt water-brackish water marsh boundary. This shift relates to salinity encroachment, which, at the same time, increases salinity gradients up the estuaries.

If indeed environmental conditions of the Barataria-Terrebonne area were nearly optimum prior to the man-induced disturbances of an established equilibrium, it follows that measures should be taken to retard further deterioration of the wetlands. This would require, when feasible, retardation, modification, or elimination of those processes and human activities that enhance a decrease of areal land-water ratio, and remove marsh surface from the estuarine system, induce salinization, and increase salinity variance. Manageable processes and activities should be therefore identified with regard to environmental effect.

MANAGEMENT OF NATURAL PROCESSES AND HUMAN ACTIVITY

Two major natural processes can be identified that are critical to the estuarine environment and to which management methods can be applied to sustain optimum conditions. These are: 1) the influx and distribution of fresh water, nutrients, and sediments, and 2) encroachment of saline waters. Past and present human activities affecting these processes include the confinement of the Mississippi River, mineral extraction, expansion of urban and industrial complexes, and reclamation.

Until construction of Mississippi River levees for flood protection, and the severance of Bayou Lafourche as a distributary, the Mississippi River provided the major influx of fresh water, sediment, and nutrients into the Barataria and Terrebonne estuaries as a result of crevassing of natural levees and overbank flow. Elimination of this river water greatly contributed to the present state of the estuarine environment.

Previous reports of the Hydrologic and Geologic Studies of Coastal Louisiana dealing with sediment requirements have attempted to establish volumes of supplementary freshwater and sediment required to partially offset land loss and to prevent further salinization (U. S. Army Corps of Engineers, 1970; Gagliano, Light, and Becker, 1971).

Of equal significance with regard to the hydrologic and salinity regimes has been the dredging of numerous canals, notably for the purpose of mineral extraction and transport, and for navigation. In the Barataria-Terrebonne region specific values can be placed on the area of wetland transformed into canals for different purposes (Plate

16). Measurements reveal a total of 106 mile^2 of canal area, which constitutes 2 percent of the total region. This does not include the wetland area modified as a result of deposition of dredge spoil on the canal banks. Of the total area of canals nearly 70 percent is related to the mineral extraction industry and includes access canals, rig cuts, and pipeline canals. Most of these are located in the brackish-to-saline marsh belt, notably in the Barataria Basin. Major oil fields show a canal density, which is the ratio unit of canal area per unit surface area, ranging between 0.15 and 0.25.

Drainage canals represent the second major category, followed by navigation canals. Drainage canals occur in restricted areas (mostly the freshwater environments), and are predominantly associated with either urban or agricultural development of natural levees, or reclamation projects for the same purposes. As a result, canals are generally in direct conflict with the natural drainage system. Their linear configuration and depth tend to accelerate removal of freshwater from the swamps and marshes, thus reducing the retention capacity of the basins. Also, dredging spoil tends to confine water movement, thereby diminishing lateral dispersion of freshwater through the estuarine system. The canals in turn, affect the distribution of freshwater temporally as well as spatially.

A third cause for disruption of the natural drainage system is a conflict between canal alignment and topography. In many cases canals dissect a natural watershed transverse to its gradient, which under the prevailing low gradient conditions is likely to direct flow from the upper watershed along the canal, thereby reducing dispersion into the lower watershed, creating freshwater deficient areas.

A similar stress arises from the construction of highways across major basins such as highway U.S. 90 between New Orleans and Houma. In those cases where the road is not confined to a natural levee or raised, the road embankments traversing the swamp or marsh severely limit the dispersion of freshwater. Freshwater runoff is redirected to a limited number of passages into the lower part of the basin provided by canals or culverts.

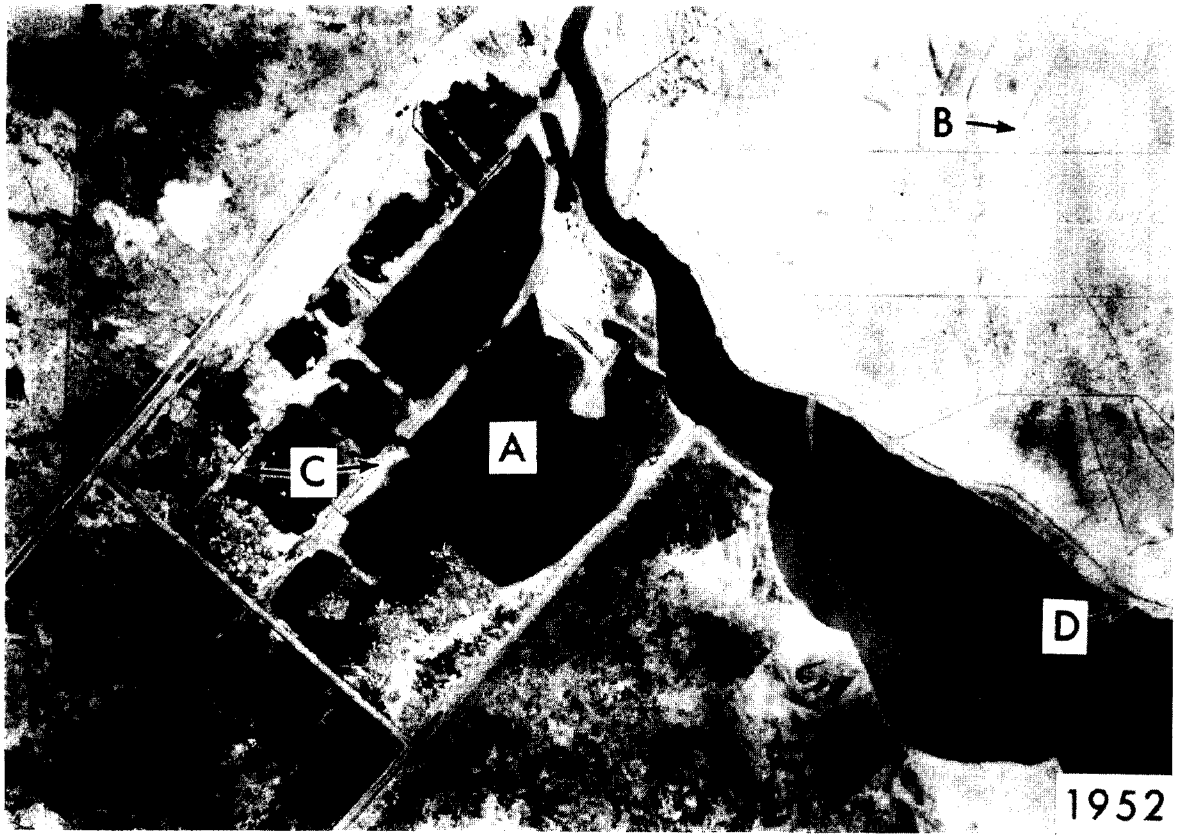
The dredging of canals has an additional effect upon estuarine conditions since it represents a physical removal of marsh surface from the estuarine system. Not only does this decrease the area of biological habitats, but it deprives the estuary of part of the influx of organic matter. In particular, the influx of organic detritus derived from the salt water marshes has been suggested as an important factor with regard to biologic productivity (Day et al., 1973).

In regard to the salinity regime, the dredging of canals, especially of those that are navigable and open to saline bays, is believed to have substantially contributed to a recorded increase of salinities over the past 25 years. This holds true particularly for the dredging of channels that provide ship access from the Gulf of Mexico to coastal communities and that traverse the shallow bays and salt and brackish marshes. The Barataria Waterway and the Houma Navigation Canal are notable examples where saltwater intrusion has been commensurate with the increase in water depths. Cypress dieback, e.g., in the vicinity of the Houma Navigation Canal near Dulac, Louisiana, is only one of the measureable ecological effects of such change.

The effects of drainage and reclamation of wetlands on the estuarine environment extend beyond the removal of blocks of swamp and marsh habitat from the natural system (reclaimed areas are identified on Plate 8). Drainage and reclamation may also contribute to formation of large water bodies. It has been documented that, in several cases, reclamation projects have failed. Examples are shown in Figures 4-1 and 4-2. Following dike construction and removal of water, the exposed, highly organic clays become subject to shrinking as a result of water loss and oxidation of organic matter. The resulting decrease in surface elevation required excessive drainage efforts that in most cases were not warranted in view of the cost-benefit ratio for the reclaimed area. Abandonment of the project subsequently resulted in flooding, creating an open water body large enough to allow wave erosion at its shores, and deep enough to prevent re-establishment of marsh or swamp vegetation.

Abandonment of drained swamp and marsh areas is mostly restricted to agricultural projects. However, in those cases where reclamation occurred for the purpose of urban expansion, notably in the New Orleans area, the result frequently is equally undesirable. The effects of soil instability require excessive structural maintenance, while subsidence requires a public expenditure for drainage and flood protection that appears unwarranted when considering available alternatives

Figure 4-1. Submerged fields, Barataria basin. Photographs show failed reclamation project at the intersection of Bayou des Allemands and La. Hwy. 90. A series of ponds such as indicated by A resulted as the reclamation project was abandoned. Drainage canals are still visible (C). Considerable enlargement of the ponds occurred over the period of 1952 to 1969. Formerly isolated from the principal drainage channel of the Barataria basin (Petit Lac des Allemands), the ponds now are connected to this water body. The shores of Petit Lac des Allemands also show signs of erosion (D). B indicates relics of overbank crevasse splays that originated along the Mississippi River.


B
A
C
D
1952

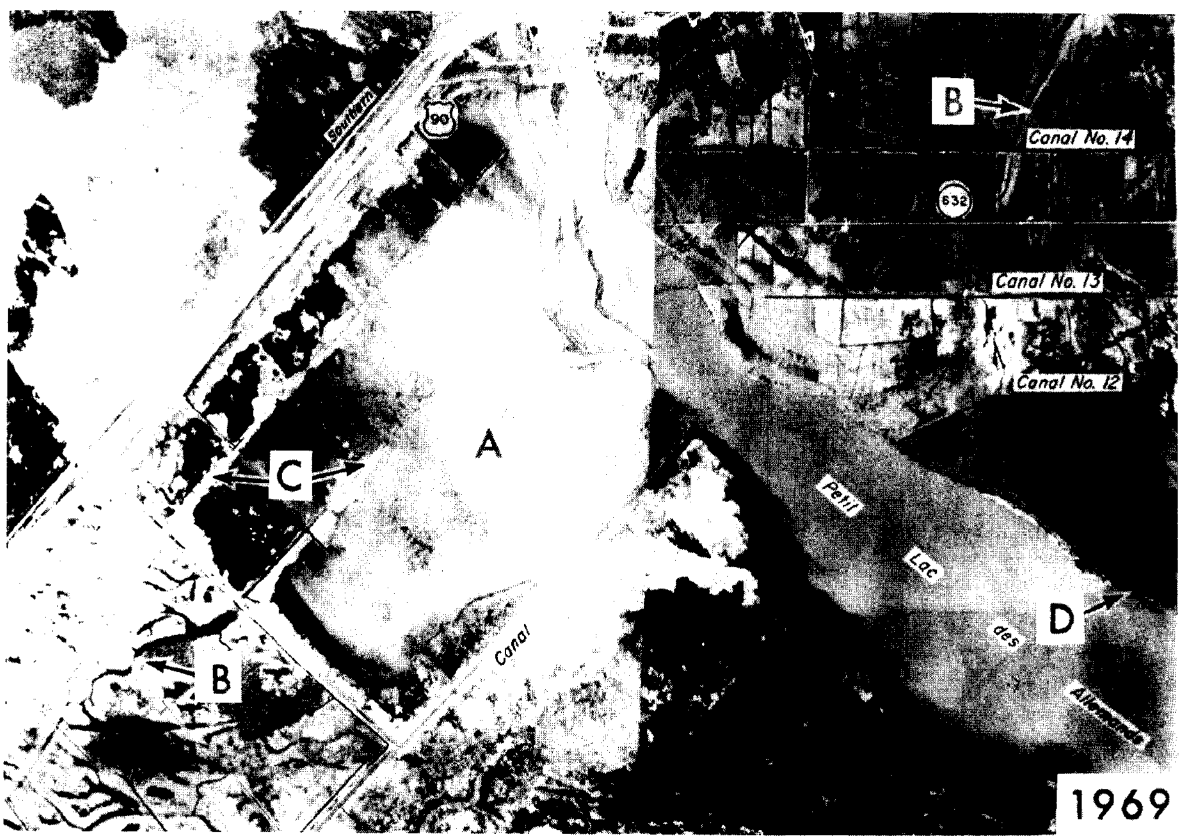
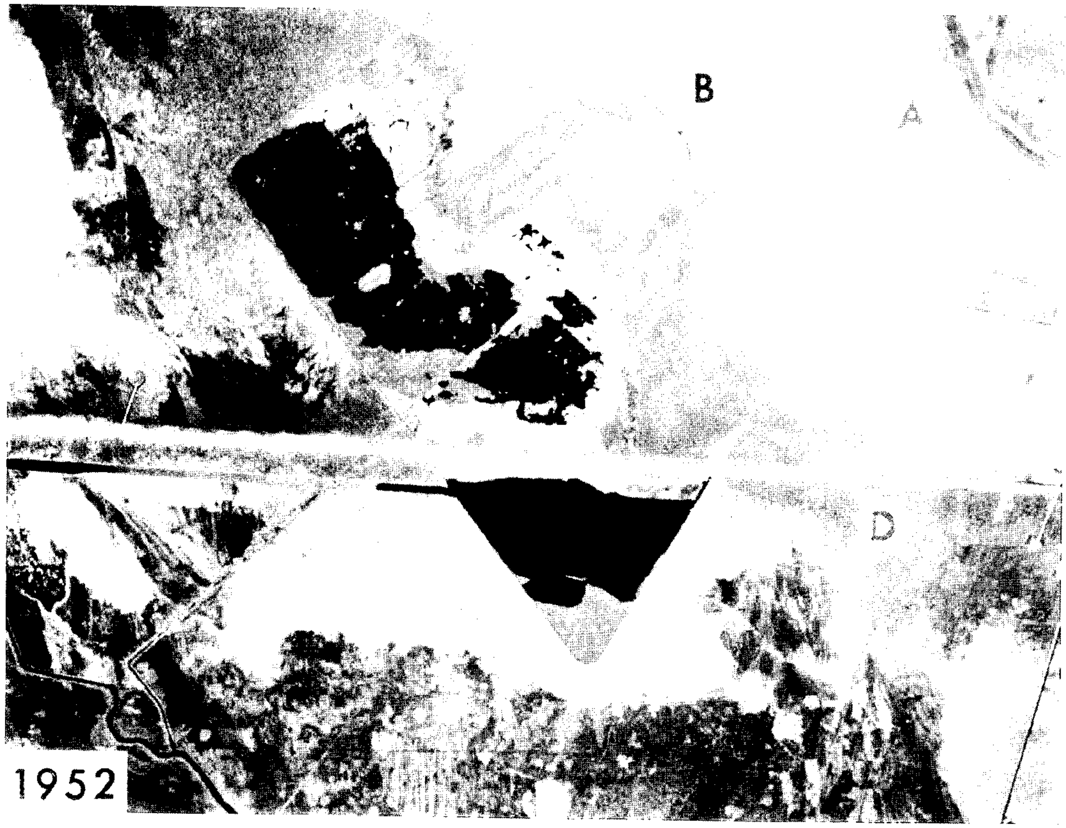

Southern
90
B
Canal No. 14
632
Canal No. 13
Canal No. 12
A
C
Petit
Lac
des
Allemands
D
Canal
B
1969

Figure 4-2. Submerged fields, Barataria basin. Attempts to expand cultivation from the natural levee of the Mississippi River (A) into the wetlands failed and resulted in the ponds shown on the photographs. Cultivated fields on the natural levee are indicated by B. Since 1952 fresh water marsh in the area has deteriorated considerably as shown by comparison of the photographs at location C. D indicates a swamp area, which forms the transition from the well drained levee to the fresh water marsh.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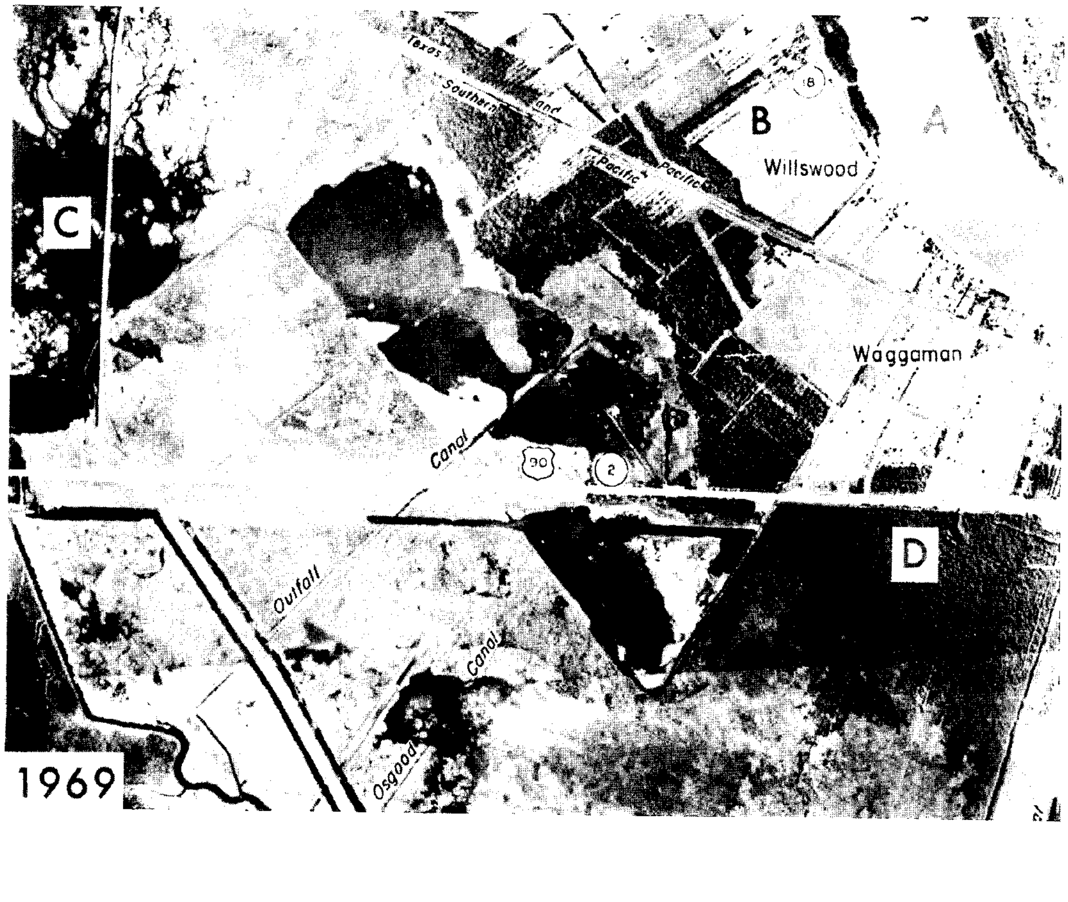
Texas
Southern
and
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Pacific
18
B
A
Willswood
C
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Canal
90
2
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Outfall
Canal
Osgood
1969

for urban development.

Shoreline retreat and deterioration of the barrier islands fringing the estuaries is among the most critical environmental problems in the area. This is because of the importance of the island chain in reducing storm generated surges, regulating water exchange between the Gulf and estuaries, as valuable natural habitats, as scenic areas, and as areas with a high recreation potential. Deterioration of the islands relates to both natural and man-induced processes. Critical factors are a limited sand budget, a continuous reworking of the barrier sediments in response to incident waves, wave-induced and coastal longshore currents, interruption of longshore sediment transport by navigation channels, and navigation and shore protection structures.

The general dynamic and geologic aspects of the two barrier systems, Isles Dernieres and Timbalier-Grand Isle, are illustrated on Plate 12. Related to shoreline orientation, dominance of southeasterly waves, and coastal currents that diverge in the vicinity of Belle Pass, net longshore sediment transport is directed to the west along the Timbalier Islands and the Isles Dernieres, to the east along most of the Caminada Beach Ridge complex, and along Grand Isle and the Grand Terre islands. Morphologic evidence suggests a convergence of beach drift in the area east of the Grand Terre islands.

In response to the general longshore drift, the islands migrate alongshore as a result of erosion at their updrift ends, and deposition at the downdrift ends in the form of recurved spits. In addition, the islands are subject to inland migration in response to a subsiding substrate. As a result of increasing water depth, sediment removed from the seaward side of the islands is in part deposited at their downdrift ends but slightly further inland. Also, sand is moved to the back of the islands by hurricane storm surges and deposited as wash-over fans.

With respect to sediment movement, the barrier chains east and west of the Caminada beach ridge complex can each be viewed as a separate open system through which sand is moved, with the barrier islands providing temporary storage. Sediment input is derived almost totally from shore erosion along the Caminada beach ridge complex. Here recession of the shore line is in the order of 50 feet annually. Sand added as a result of reworking of the subsided and submerged deltaic plain surface over which the islands migrate is probably negligible in comparison. During longshore transport of sediment derived from the beach ridge complex or released from storage in the islands, sand is lost temporarily or permanently. Temporary losses result from the movement of sediment into the bays by flood tidal currents and subsequent deposition as tidal deltas inland from the passes. This sediment may in part be reincorporated following inland migration of the islands. Permanent loss of sand results from offshore movement of sediment by tidal currents and wave motion, and from deposition at depths that are below the lower boundary of sediment reworking during migration of the barrier system.

A critical factor with regard to longshore sediment movement is the presence of an arcuate bar seaward from each of the major tidal passes connecting adjacent barrier islands. The bars are, in essence, formed by deposition of sand from ebb tidal currents. Limited water depths over these bars allow continuous entrainment of sediment in this area so that in combination with longshore process components, the bar provides for natural bypassing of the tidal inlets. This insures sediment input on island downdrift from each inlet.

The above described general dynamic framework of the barrier system allows indication of a number of human enterprises that can be considered detrimental to the prolonged existence of the barrier islands. These are the placement of structures perpendicular to the shore line, the dredging of tidal passes, and the dredging of numerous canals along the backshore of the islands--notably Timbalier Island. The dredging of tidal passes affects both the sediment budget and sediment movement. Since the offshore bar associated with the passes is the main obstruction to navigation, dredging tends to include the removal of part of the bar. This reduces the possibility for sediment to bypass the inlet, thus partially depriving downdrift islands of necessary sediment input. Furthermore, sediment entering the dredged channel will in part be moved offshore and in part be withdrawn from the system as it is incorporated in reestablishment of the bar. Offshore sediment movement, as well as movement into the bays, may be increased when dredging induces velocity increase of the tidal currents through the inlet.

Placement of groins and jetties may also cause serious interception of sediment in longshore transport, depending on storage capacity of the updrift area. Storage in the updrift area consequently reduces the input of sediment downdrift which will, under the present circumstances, result in serious erosion. Even though sediment input may be halted only temporarily, the erosion may do irreparable damage to those barrier islands which hold only a very limited amount of sand in storage. For instance, thickness of the sand deposits making up the Isles Dernieres is only on the order of 5 feet (Plate 12). Since most of the islands also have a critically small width, even slight additional short-term erosion may result in a breaching of the island and complete deterioration. In this respect it should be pointed out that the chain of barrier islands is no stronger than its weakest link. That is, the complete deterioration of a single island may result in a wide tidal inlet and a long-term reduction of sediment input into downdrift islands. The deterioration process thus could be perpetuated.

Notable effects of engineering works are found on the Grand Terre Islands, East Timbalier and Timbalier Island. Erosion of the Grand Terre Islands has been accelerated as a result of the long jetty built at the eastern end of Grand Isle for the purpose of creating a sand storage reservoir. Dredging of a new Belle Pass inlet channel adjacent to and replacing the original channel greatly accelerated erosion along East Timbalier. Comparison of the 1953 Belle Pass topographic map, and 1968 and 1972 aerial photography, shows that shoreline retreat over the period of 1968 to 1972 following completion of the Belle Pass channel approximately equaled retreat over the period of 1953-1968. This means a fourfold increase in the rate of shoreline retreat. The effect of a jetty placed near the western end of East Timbalier Island has resulted in a significant landward offset of the downdrift shoreline and breaching of the spit extending westward from the jetty.

A major factor contributing to deterioration of the islands is the dredging of canals for mineral extraction purposes on the bay side of the islands. Such canals are evident on Timbalier Island, East Timbalier Island, the easternmost side of the Isles Dernieres, and the Grand Terre Islands. These canals make the islands highly vulnerable to breaching, a condition that is further enhanced by the migration of the islands which places the canals ever nearer the seaward margin. Not only may breaching occur as a result of wave runup on the seaward side, but part of a returning storm surge in the bays will be directed into the canals, resulting in amplification of the surge height. The canals further form a sediment trap resulting in withdrawal of sand from the barrier system. Here again, even though storage of sand in the canals may be temporary, the islands may not be able to absorb additional decreases in sediment input.

MANAGEMENT PLAN

Through the outlined approach involving simultaneous consideration of geologic and hydrologic processes, human activities, and key environmental parameters, it has been possible to arrive at a plan for management and development of the Barataria-Terrebonne area, including both its land and surface water resources. Plate 21 of the atlas presents the multi-use development and management plan. As the plan attempts to sustain or produce an optimum environmental balance through recognition of environmental units with specific constraints and opportunities, it indirectly identifies present and proposed activities and projects that are incompatible with optimum use of the area. These conflicts are identified on Plate 22. An additional need that has been recognized is the use of innovative engineering approaches in the design of projects necessary for implementation of, for example, water diversion or shore protection. Such projects should become assets to the overall environment rather than being directed to only the technical solution of a design problem. Thus the problem also becomes one of environmental engineering.

Management and Development Areas

The management and development plan is based upon two major concepts. The first is that of a corridor-basin relationship. Within the coastal zone are two broad, natural land systems: the natural and protected levee ridges where historically human settlement has taken place, and the wetlands that throughout history have been the major renewable resource base of the state. The plan recognizes the value of this physiographic and historic pattern by emphasizing the levee systems as transportation and development corridors, and stressing conservation of the wetlands as water system recharge and natural resource development areas.

The second concept recognizes the need for successive and changing land use in an orderly and sequential manner. This is necessitated by the dynamic nature of the natural systems of the coastal zone. We must recognize and accommodate natural changes by modifying land use through time. The system cannot be held in a static condition.

The concept of sequential use can be extended to man's activities. Facilities for mineral extraction, industrial plants, and certain public works projects have a limited life expectancy. When such facilities are designed, an attempt to predict some future land use of the site should be made to avoid irreversible environmental modifications that are not compatible with predicted future use.

The map (Plate 21) presenting the management and development plan shows the five types of environmental units that are recognized. Each unit is characterized by a specific set of natural and cultural elements that determine its optimum use. The units represent natural entities with their boundaries determined by natural contacts, ranking of environmental constraints and opportunities, and by historic and projected land use patterns. The defined environmental units are: Barrier Island and Gulf Shore Areas, Estuarine Nursery Areas, Fresh-Brackish Marsh Areas, Freshwater Basins, and Development Corridors.

Barrier Island, Reef, and Gulf Shore Areas

These areas represent the first line of defense against hurricane forces and marine processes, and are the key to regulating water exchange between the estuaries and the Gulf of Mexico. Tidal passes associated with the barrier islands can be viewed in part as control valves of the estuaries. The islands furthermore are invaluable as wildlife habitats and scenic recreation areas. Large shell reefs in the Point au Fer area represent a coastal barrier as well.

In particular, the barrier islands are undergoing rapid changes as a result of coastal erosion (Plate 12). Accelerated regional subsidence, hurricane damage, and man-induced changes such as dredging of canals on the bay side of a number of islands are the main contributing factors. Frequent hurricanes and coastal erosion are a continuous threat to life and property where permanent development occurs. This is well illustrated by Grand Isle, even though this is the most stable of the barrier islands. The island is accessible by highway and has become important as a recreation area, as a base for the offshore oil industry, and as a fishing port. This development and the related shore protection are incompatible with the necessary sustenance of certain coastal processes and optimum use of the islands. Similar permanent development of other barrier islands should be discouraged.

It is recommended that top priority be placed on management of these units as natural barriers against marine forces (including tidal inflow and outflow of Gulf water) and as wildlife and scenic-recreation areas. Their maintenance is vital to the continuing viability of other natural systems in the coastal zone. The only feasible approach to maintenance of the barrier islands is to insure continuity of the wave- and current-driven system of sand nourishment and redistribution. The nourishment sources for the barriers in the study area are old beach ridges and channel deposits. The sand is released through erosion of these deposits. For this reason erosion along some segments of the coast must be allowed to continue. A specific example is found in the vicinity of Pass Fourchon.

Longshore sand transport should not be disrupted by channel deepening or the construction of jetties. Sand transport across natural tidal passes is accommodated by arcuate bars that span the full width of the pass on the seaward side. When these bars are dredged for navigation improvement the transport system is disrupted by allowing increased escape of the sand from the longshore drift system. This in turn results in accelerated erosion on the downdrift side of the pass unless provisions are made for sand by-passing. Sand by-passing plants have been used in other areas to alleviate such problems.

The barrier islands must be maintained in order for the existing estuarine system to flourish. Detailed studies of erosion and deterioration of the barrier islands should be initiated immediately in order to implement restoration and management. These studies should address a number of problems related to sand nourishment and transport. Specifically, studies should be made of 1) sources and quantities of sand available for supplementary nourishment; 2) the advisability of attempts to maintain the shoreline of Grand Isle in its present position when viewed in relation to the overall barrier system and the effect of subsidence; 3) possibility and desirability of preventing breaches in barrier islands such as East Timbalier Island; 4) feasibility of closing enlarging tidal passes such as those of Grand Terre Islands; 5) the sand budgets for individual islands, barrier complexes, and the barrier system as a whole in order to allow for long-term planning and management; 6) the possibility of bringing the islands into public ownership. They are so vital to the future of the coastal zone that they should be in the public domain since present regulations related to private ownership prevent effective management and restoration.

Estuarine Nursery Areas

From the standpoint of biological productivity, the estuaries represent the most productive acreage in the state. Not only are they the foundation of the state's fishing industry, but they provide important habitats for migratory waterfowl, fur-bearing animals, and reptiles, and are important scenic-recreation-open space areas. The units are defined on the basis of distributions of salinity, marsh vegetation, oyster beds and length of land-water interface per unit area.

These areas should never be drained or reclaimed for other uses, even agriculture. Recent overflights indicate that thousands of acres of marsh in the estuarine nursery areas are in an advanced state of deterioration. Programs of marsh restoration and management should have the highest priority and should be initiated immediately. Such programs should include a detailed systematic evaluation of the marsh condition followed by a water management program designed to conserve runoff, reduce salt water intrusion, and curtail erosion.

Although the map is intended to be a clear statement that the primary management objective in these units is for renewable resources, we also realize that mineral extraction industries are active in these areas. If it becomes necessary to drill new wells, develop new fields, or lay new pipelines, the surface modification associated with these activities must be made compatible with the primary management objective.

The concept of sequential use is also important. Since an oil field has a life expectancy of 35-70 years, we must plan for future use of areas now occupied by fields. In many instances, creative planning of canal geometry and spoil disposal could create new habitats, conserve freshwater runoff, and enhance the environmental setting. In general, canal dredging should be minimized. Directional drilling should be used to reduce the number of well locations and pipelines should be confined to corridors. Surface features should be considered in all future mineral industry planning. These same guidelines apply to extractive industry activities in all of the renewable resource management areas, and will not be repeated.

Fresh-Brackish Marsh Areas

Largely unbroken fresh to brackish marshes and associated lakes, ponds and waterways occupy a major portion of the estuarine zone adjacent to the Gulf Intracoastal Waterway (GIWW). They are delineated on the basis of distributions of salinity, fauna and flora, configuration of streams and water bodies, and length of water interface per unit area. Like the estuarine nursery areas, these marshes are vital components of the highly productive estuarine zone. They are of primary importance to migratory waterfowl, fur-bearing animals, and commercial species of reptiles (alligator). They provide scenic-recreation-open space areas, and are of considerable value to the commercial fishing industry. In addition, these marshes, along with other renewable resource areas located south of the GIWW, provide a critical buffer zone against storm generated surge and prevent serious inundation of inland communities. With regard to land use, it should be pointed out that in these units, thick underlying deposits of peats and soft clays provide poor foundation conditions.

Priorities and management recommendations are essentially the same as those outlined for the estuarine nursery areas.

Fresh Water Basins

Three major fresh water basins are identified on the map. All lie north of the GIWW. They are dominated by extensive swamps and marshes, rounded lakes, and sluggish backswamp drainage networks. They are usually underlain by thick deposits of peat and organic clay, which provide very poor foundation conditions and limit land use. Their value as wildlife habitat areas is well known not only to the sportsmen and naturalists of the region, but to a large segment of the general public as well. These basins are also important as natural reservoirs ensuring fresh water flow into the estuarine zone south of the GIWW throughout the year. This fresh water influx is one of the primary factors in controlling water chemistry in the estuarine zone south of the GIWW. Alteration of the flow regime in some of these basins through drainage projects, canal dredging, flood control projects, and highway embankments is presently one of the major factors in increased salt water intrusion in the estuaries.

These basin must be managed as renewable resource areas. Forestry, fisheries, and recreation are the main uses recommended. Dredging should be minimized, and draining and reclamation prohibited. In most instances, highways traversing the basin should be elevated on piers or piles. In general, introduction of any new linear elements should be discouraged. If unavoidable, they should be confined to corridors parallel to existing highways, pipelines, etc. Water storage in the basins should be managed in order to optimize water chemistry in the estuaries to the south.

Existing corridors traversing these basins should be de-emphasized from the standpoint of development. For example, U.S. Highway 90 between Boutte and Raceland is an important transportation link, but should not be encouraged as a development corridor.

Guidelines pertaining to the mineral extraction industry are essentially the same as those proposed for estuarine nursery areas. In addition, construction of tramways or roadway embankments in inland swamps and marshes should be minimized. Such features often redirect fresh water runoff in the basins and provide obstacles to the movement of aquatic and terrestial animals.

Development Corridors

In general, areas suitable for development are those places that have good foundation conditions, good drainage, and are reasonably safe from flooding. Natural levee ridges form the higher, positive topographic elements in the Barataria-Terrebonne region that are designated as suitable for development. Historically, agriculture, industry, and settlement have been largely restricted to these areas. Attempts to extend these activities to adjacent wetlands have often proved to be catastrophic.

The key to proper use of these areas is careful planning. A good mixture of urbanization, industry, and agriculture in these areas will insure both orderly growth and economic development and a good place for people to work and live. Soil and meteorological conditions should be mapped in detail and suitability for agriculture ranked. Prime agriculture areas should be identified and promoted in every way possible.

The development corridors are primary elements in the proposed multiuse management plan. They represent areas that are already heavily developed or where development is projected. In most cases, the corridors are confined to land surfaces that are suitable for development. In some instances, however, "natural" corridors have been expanded to boundaries formed by prominent man-made features, such as major navigation canals or flood protection levees. For this reason, some of the land included within the development corridors has poor foundation conditions and is flood prone. The rationale for expanding some natural corridors is to provide adequate area for development so that random extension into renewable resource areas can be controlled.

In addition to land suitability, locations of development corridors are dictated by major land and water arteries, historic land use patterns, and the necessity to maintain rather than dissect existing natural entities. The term "development corridor" is not meant to imply blanket urbanization or industrialization. Creative planning is again recommended to provide the best mix of land use in these areas. The primary use, however, is for development.

Public works projects should be focused on the corridors to strengthen and further define them. Highways, flood protection levees and structures, and drainage projects, should be incorporated into the corridor plan. Such projects should be combined wherever possible to minimize land acquisition and costs. There is no reason, for example, why highways cannot be constructed on the crests of levees. This is a standard procedure in the Netherlands and many other parts of the world. Water resource management, mass transit systems, and regional waste collection treatment systems should likewise be incorporated into the corridors, as should linear elements such as pipelines and power lines.

The contact between corridors and intervening resource management areas presents an interesting challenge to the planner. Should it be smooth or crenulated? Should access points between development corridors and marshes or swamps be linear or nodal? Only detailed environmental analysis can provide the answer to these specific planning and design decisions.

In some instances, the continuity of a development corridor depends on a transportation link across a wetland area. A classic example occurs between Lafitte and Larose. We believe that a transportation link between these two places is important to orderly development of the coastal zone. It is also recognized that excessive development across this area is likely to cause a serious deterioration of the rich Salvador-Barataria estuary system. In these instances, we propose, therefore, that future highways be elevated on structures with permanent restrictions against off ramps. This same principle can be applied in a number of critical areas; notably, in the St. Charles Parish wetlands along the south shore of Lake Pontchartrain where I-10 and I-410 will join.

Geometry for Development

The development corridors shown on the plan represent an excellent geometry for future growth and development of the study area that is compatible with management of renewable resource areas. In a broader context, the corridor should be viewed as part of a great oval linking Lafayette, Baton Rouge, Hammond, Slidell, New Orleans, Larose, Houma, Morgan City, Franklin, and New Iberia. This oval-shaped corridor is one of the most basic elements in the orderly use of the overall coastal zone (Fig. 5-1). Reinforcement of this corridor would have highest priority. The southern Lafayette-Houma-Slidell arc is of particular importance. An interstate highway along this arc would be very important. Improved transportation along this arc would provide easy ingress and egress to the coastal zone, making its opportunities available without necessitating overpopulation. Urbanization should be encouraged on the well-drained surfaces near the poles of the oval. The Slidell-Hammond-Baton Rouge area and the Opelousas-Lafayette-New Iberia area satisfy most of the site requirements for good urban development. Much of the southern arc of the oval is suitable for urbanization, though on a somewhat reduced scale. The Thibodaux-Houma area, for example, should eminently provide for urban growth. The channels and natural levee ridges of the Mississippi River and Bayou Lafourche represent major trans-coastal development corridors, and the State's most important gateways to the Gulf. This corridor should be reinforced, although its capacity must be determined. Is there a limit to industrialization in this corridor, or can every acre of the natural

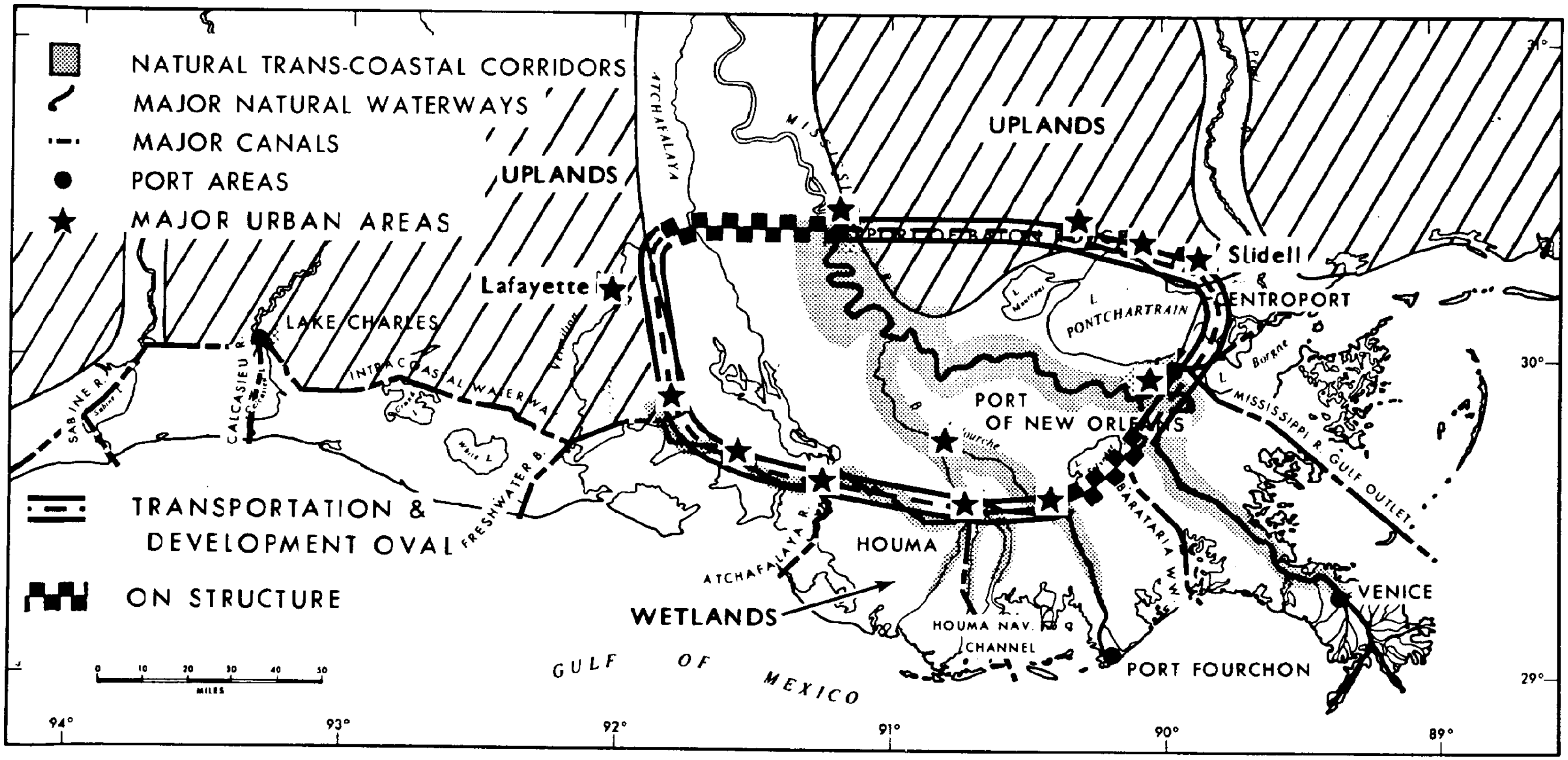

Figure 5-1. Major elements for growth and development of the Louisiana Coastal Zone.

levee be utilized? The banks of the Mississippi River are already lined with industry, and many additional plants are anticipated. Air and water pollution are an inevitable consequence of this industrialization. To what extent can the natural system absorb even a minimum of pollutants?

Despite these unknowns, the Mississippi River is and will continue to be the State's most valuable asset. The lower end of the Mississippi corridor should be reinforced. Venice is destined to become an even more important support facility for the offshore oil and gas industry and future superport development.

The Lafourche corridor should be reinforced with improved highways and flood protection. However, flood protection levees should not be extended south of Golden Meadow. The proposed Lafourche by-pass channel would define the western margin of an expanded natural corridor. The beach ridge complex near the mouth of Bayou Lafourche at Port Fourchon may serve as a foundation for onshore port facilities, related to a deep water harbor. Although some port facilities may be permitted, permanent development of petrochemical or other heavy industry should be discouraged because of incompatibility with recreation uses and maintenance in the adjacent Gulf Shore areas.

Minor trans-coastal corridors within the study area include Bayou Grand Caillou, Bayou Petite Caillou, Bayou du Large, and the Atchafalaya River. Each of these corridors will play an important role as outlets for recreation, the fishing industry, the offshore mineral industry, and to some extent, as commercial ports. However, further widening and deepening of associated navigation channels is discouraged because of the salt-water intrusion problem.

The roles of other minor development corridors in the upper coastal zone are apparent from their locations and form. The geometry of the development corridors and environmental management units lends itself well to evaluation of both the proposed deep water port to be located off the Louisiana coast, as well as regional air carrier terminals. Elsewhere (Gagliano, van Beek, Rowland, 1973) we have indicated that the best probable site for the superport would be in the west delta area near Southwest Pass. Only the Mississippi corridor can service, with minimum impact, an initial oil port and later stages of the facility which may include containerized and break-bulk cargo handling.

There is presently a rash of proposals for new towns and harbor towns in the coastal zone. A number of these proposals involve the use of public lands or require government assistance in the form of flood protection, drainage, access roads, and other aspects of site preparation. A number of the proposals would involve significant loss of wetlands and create major water pollution problems. There are many excellent sites for new towns within the development corridors and those areas suitable for development. The consumer will pay heavy penalties in increased site preparation, maintenance costs, and tax burdens for any urbanization or development in the wetlands areas of the coastal zone. All land reclamation, including "Florida-type" canal and homesite developments, for urbanization should be prohibited.

The new community concept is an excellent one. New town property placed within development corridors would guarantee a more orderly growth of the region. A limited number of harbor towns at carefully selected locations would also be a major asset. However, the locations should be pre-determined by the geography and hydrology of the region, and not simply by the wishes of the land developers. Since harbor towns can have major environmental impact, additional study is recommended to determine favorable locations and sizes.

Surface Water Resource Managment

Management of surface water can be considered the most important single part of the overall plan. This is because the wetland-bay complex represents the major renewable resource of the study area, and the viability of this complex depends primarily on its hydrologic and salinity regimes. The surface water management plan as presented in Plate 20 of the Atlas is aimed at establishing the most favorable ecological condition through management of the regimes by means of controlled retention and release of fresh surface water.

To establish optimum ecological conditions, it is necessary to prevent further deterioration of the wetlands and to maintain or restore the broad mixing zone that initially resulted from a natural balance between locally derived runoff, water introduced by overbank flow of the Mississippi River and its distributaries, and exchange with saline waters of the Gulf of Mexico. This balance, as well as the overall estuarine environment, has increasingly been subjected to stress as a result of diminished fresh water influx related to levee construction, reduced fresh water retention and diffusion as a result of canal dredging and drainage projects, and increased salinities related to both of the above. Consequently, the three main elements of the surface water management plan are 1) the introduction of supplementary fresh water, 2) the conservation or retention of runoff, and 3) the release and distribution of fresh water.

The plan is based on earlier derived quantitative relationships between salinity fluctuations within a given hydrologic unit and fresh water runoff derived from precipitation within that same unit (Gagliano et al., 1970). These relationships in turn made it possible to establish the volumes of supplementary fresh water required to maintain desired salinity conditions as defined by the positions of the 15 ppt isohaline and the brackish-salt marsh contact (U.S. Army Corps of Engineers, 1970; Gagliano, Light, and Becker, 1971). Water needs for hydrologic unit IV, the Barataria basin, and hydrologic unit V, the Terrebonne area, are shown by frequency of need in Figures 5-2A and B, respectively. Locations and maximum volumes of fresh water diversion into these units are shown on Plate 20 .

A principal element in the management of the hydrologic and salinity regimes is the reinforcement of three fresh water basins north of the Gulf Intracoastal Waterway (GIWW) as retention areas. These basins are identified on Plates 20 and 21 as the Verret, Fields, and Salvador Basins. Three major diversion structures are proposed for the introduction of fresh water into these basins from the Mississippi and the Atchafalaya Rivers.

As each basin is contained between natural levee ridges, construction of a continuous levee system along the GIWW would allow each basin to function as a reservoir where fresh water can be held in order to meet demands during period of precipitation deficit and increased salinities in the lower estuaries. The levee is proposed along the southern side of the GIWW to allow use of this waterway as a conduit interconnecting the fresh water basins, and for redistribution of water along a continuous arc fringing the estuarine area into which fresh water is to be introduced.

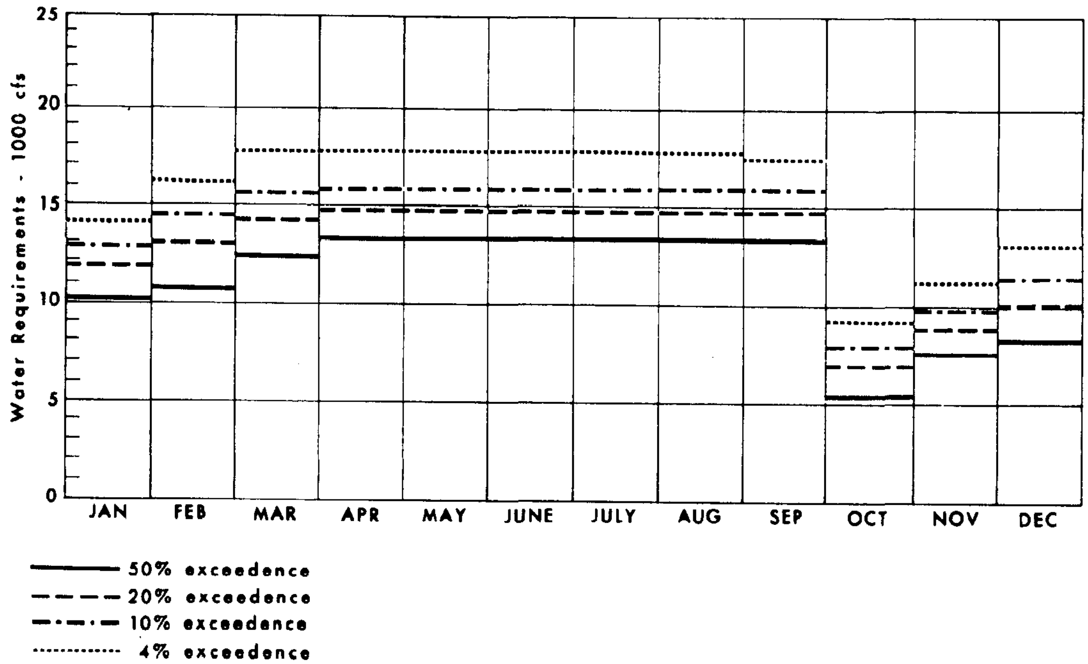

Figure 5-2A. Preliminary water needs for salinity alteration and/or water-level management, hydrologic unit IV.

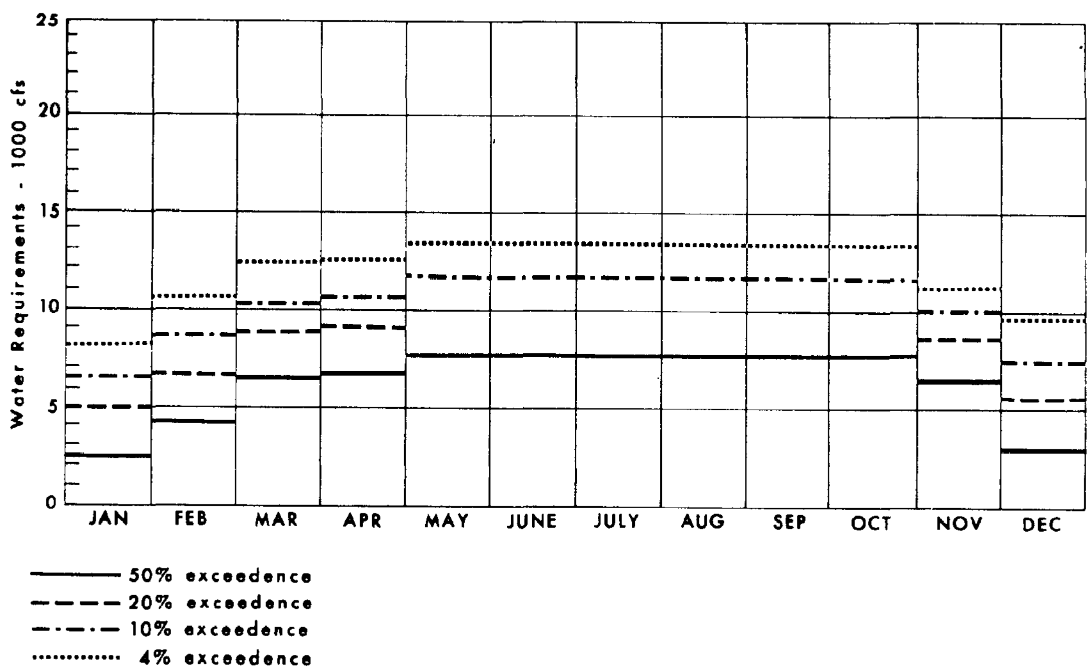

Figure 5-2B. Preliminary water needs for salinity alteration and/or water-level management, hydrologic unit V.

Locks would be required where major waterways connect with the GIWW.

The conversion of the present basins to fresh water reservoirs is not to mean the creation of three continuous lakes. Rather, the retention of fresh water in these areas should be part of a managed backwater regime in which water would not be raised by more than one or two feet above the present levels.

To effectively manage the supplementary water, two options are envisioned with regard to its release from the fresh water basins. The first is a release through the proposed locks on the major navigation channels connecting the basins with the Gulf of Mexico. This would allow removal of excess water from the basins without significantly affecting the managed estuarine conditions.

The second manner of release would be directed toward management of the estuarine conditions. It would require the diffusion of fresh water through the estuarine system at all times when salinities need to be reduced or the encroachment of saline water checked. For this purpose, a large number of delivery structures is proposed through which water can be slowly released from the freshwater basins and GIWW into the marshes to the south. The release schedule through these structures should be dependent entirely upon management requirements for marshes, estuarine nursery, and oyster grounds.

An integral part of the surface water management plan is the direct reduction of salt water influx by whatever means are warranted. At present, a number of tidal weirs are in operation for the purpose of marsh management. Extension of this network across major tidal channels should be encouraged.

Of major significance with regard to salt water intrusion is the deterioration of the barrier islands. The increase in cross-sectional area serving the exchange of water between the estuaries and the Gulf, together with diminishing protection from wave action and storm surge, greatly enhance salinization. Maintenance of the barrier islands is a fundamental part of the water resource management plan.

Environmental Engineering

When coastal Louisiana was in a virgin condition, nature did a superb job of environmental management. Balanced environmental conditions resulted in high biological productivity, and, in general, the system was self-maintaining. Erosion occurred along some parts of the coast, but this was more than compensated for by the new land built in the vicinity of the active outlets of the river.

Man's impact has caused serious imbalance in the system. One symptom is massive marsh deterioration and land loss. Land in the coastal area is being lost at a staggering rate of 16.5 square miles per year and a 30 year loss of almost 500 square miles has been measured. It is not an exaggeration to say that the delta is dying.

We must restore the delta and manage it to optimize natural productivity. This can be achieved by directing natural processes. For example, the freshwater outflow and transported sediment load represent a tremendous amount of energy and supply of materials. The delta has literally been constructed by this energy source and material supply. By redirecting flow and helping the river to initiate new cycles of delta building, new marsh lands and estuaries can be built.

The most favorable locales for controlled delta building are along the lower reaches of the Mississippi River and the outlets of the Atchafalaya River in Atchafalaya Bay. Even though these areas are marginal to the present study area, secondary effects resulting from changes in outflow and sedimentation patterns would have profound effects throughout the coastal zone.

The Atchafalaya has been building a marine delta lobe since about 1950 and if not interrupted, some 100 square miles or more of new marsh land will have been added to the coast by the year 2000 (Garrett et al., 1969; Shlemon, 1972). Similarly, for relatively small investments of flow and sediment, very large areas of land could be constructed along the lower Mississippi River in relatively short periods of time (20-50 years). Based on average rates of deposition in modern subdeltas, it has been shown that for an annual investment of 5.8 percent of the Mississippi flow including 17.9 million tons of sediment, an average land gain of 0.57 mi^2/yr could be anticipated at four sites between Quatre Bayou Pass and Grand Pass (Gagliano, Light and Becker, 1971).

The places at which controlled fresh water diversion structures intersect development corridors provide exceptional opportunities for environmental engineering and creative planning. A schematic configuration for such a location is presented in Fig. 5-3. Proportions are taken from the Myrtle Grove area in Plaquemines Parish along the west bank of the Mississippi River. As shown in the figure, a diversion canal would cross the corridor and would provide the conduit for supplementary water introduced into the flood basin area. Flow would be regulated by a control structure. At the basin side of the corridor, the diversion canal would open into a stilling lagoon where, upon abruptly losing

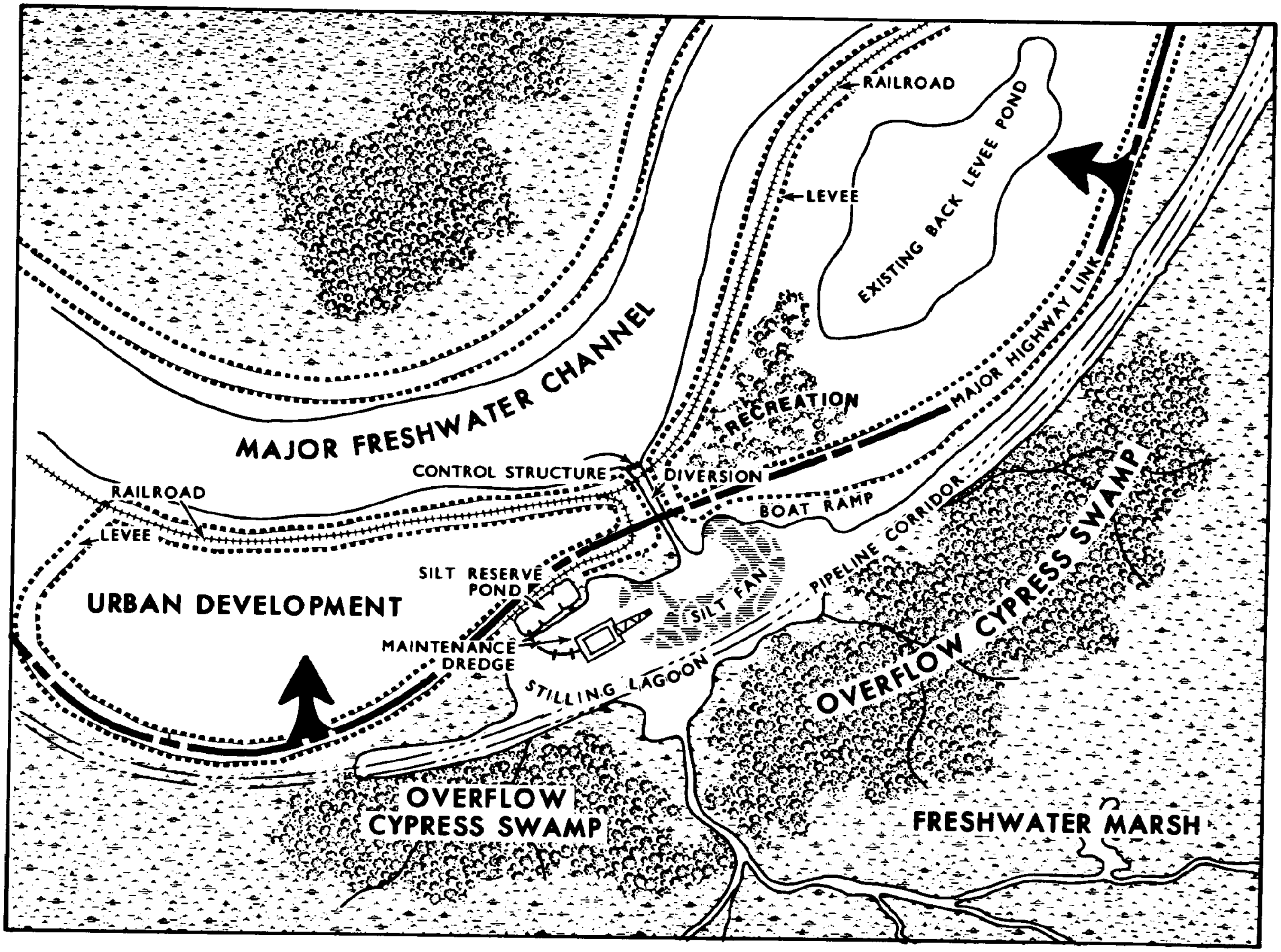

Figure 5-3. Schematic plan for environmental management and land use at intersection of freshwater drainage canal and development corridor.

velocity, the diverted water would deposit the coarser fractions of its transported sediment load. In all probability, a silt fan would form in the vicinity of the canal mouth. A small maintenance dredge would periodically remove this silt and discharge it through tail pipes into compartmented silt reserve ponds along the stilling lagoon margin. Here, the dredge slurry would be de-watered and used for construction purposes. The stilling basin would extend parallel to the river and development corridor, becoming narrower with increasing distance from the diversion canal mouth. This zone would also be designated as a pipeline corridor and initial dredging might be done in conjunction with pipeline construction. In those areas requiring maintenance dredging, the pipelines would be laid at sufficient depth so that they would not be damaged by dredging.

The flood basin side of the lagoon and canal system would interface directly with wetlands. Here, the artificial introduction of sediment-laden river water would recreate conditions like those which formerly existed along natural levee backslopes. Such a situation is ideally suited for cypress-tupelo gum swamps. Cypress could be planted initially and would propagate itself under managed overflow conditions. Small overflow streams would meander through the overflow swamps providing ingress into flood basin marshes, both for supplementary water and for sportsmen and other visitors.

The development corridor itself should be reinforced with a major highway system on or in the immediate vicinity of the back flood protection levee. The flood protection area within the corridor, situated on the relatively firm natural levee ridge, would be developed for urban, industrial and recreation uses. This type of configuration not only provides for good use of renewable resources, but also takes maximum advantage of environmental opportunities for growth and development. Unit planning of multi-functional structures, such as highways and flood protection levees, or bridges and control structures, will often yield a savings in cost, environmental impact, and land dedication. This kind of arrangement has specific application along the banks of the Mississippi River and along a number of other major freshwater channels.

Erosion control is fundamental in the coastal zone, but is especially challenging, as there are over 15,000 miles of land-water interface in that part of the study area south of the GIWW and much of it is eroding. One approach to erosion control along the muddy shorelines of large lakes and bays could be the construction of barrier islands. As shown in Fig. 5-4, the islands would typically be 1/4 to 1/2 miles in length and separated from the shore by a shallow lagoon. Passes would be left between individual islands. The islands would be constructed around a rigid structural core of interlocking metal sheet piles, concrete tetrahedrons, or some similar skeletal material. The body of the islands would be composed of lake or bay bottom sediment supplied by suction dredges or large drag lines. The seaward edge of the islands would be veneered with gravel, sand, shell, or some other coarse grain material that would absorb wave energy. The (tidal) passes would be lined with rip-rap or some other rigid, erosion-resistant material. A soft edge would be left on the lagoon side of the islands and would be planted with marsh grass.

Assuming that model studies will show physical feasibility of this type of erosion protection, it has a number of important advantages even though it would be relatively expensive. Islands would not only prevent

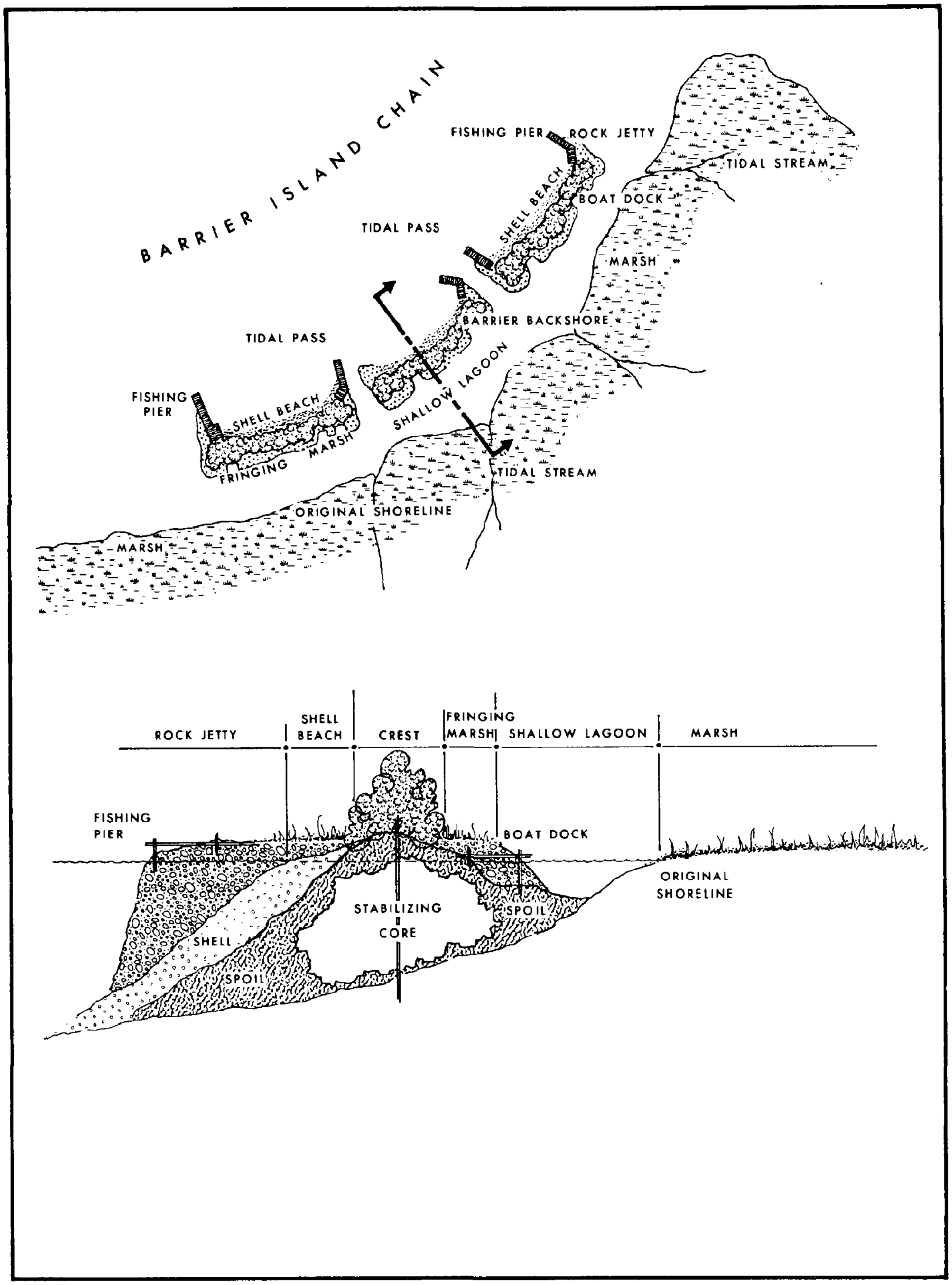

Figure 5-4. Configuration of proposed man-made barrier islands.

erosion, but would also reduce storm surge without destroying the important land-water interface along the estuary margin. Marshes and swamps could be maintained in a natural condition landward of the lagoons. The islands would not only reduce significantly the erosion problem without damaging the estuary, but would actually enhance the total environment.

Island construction would create new, more diversified habitats. These would include beaches, vegetated island crests, lagoon fringing marshes, tidal passes, and lagoons. Increased recreation opportunities resulting from this approach are particularly attractive. The beaches and passes would be ideal for surf fishing and other water contact recreation. Island backslopes and crests provide picnic areas and camp sites, and lagoons could function as small boat shelters. The new natural environments could also provide for wildlife and fish habitats. These would include lagoons for oyster beds, passes for fin fish and crustaceans, fringing marshes and lagoons as estuarine nursery areas and habitat for migratory waterfowl, fringing marshes and regulated island crests as mammal and reptile habitats, and beaches, passes, and island crests as habitats for shore and wading birds.

As shown on the map, man-made barrier islands should be constructed on the margins of large lakes and bays in places where the wetlands are of high value for recreation and/or as nursery areas and wildlife habitat. Typical applications would be along the margins of Lake Salvador and Little Lake, where erosion is not only destroying valuable marshes, but also is destroying a number of archaeological sites.

The barrier islands illustrate an important concept of environmental engineering. That is, if energy and resources must be expended to solve a problem, it is often possible to reap additional benefits by creative planning. Subtle changes in elevation and geometry alter natural processes to create favorable opportunities for desirable flora or fauna. The same approach could be applied to the geometry of oil field canals and spoil disposal sites that might result in environmental enhancement instead of deterioration for the same expenditure of energy and resources.

Nature may well have provided the study area with unique possibilities for solving problems of regional waste collection and disposal, possibilities that should be further investigated. The first relates to the nutrient value to the estuarine system of urban sewage if bacteria can be eliminated. Pilot studies of marsh enrichment are presently in the planning stage by environmental scientists at the Center for Wetland Resources. A second possibility that may be of considerable value concerns the generation in reaction chambers of methane gas and other usable by-products. Plate 14 shows the presence in the study area of a large number of subsurface salt domes, several occurring at limited depth. An example of such a dome is shown in Figure 5-5 . These domes would allow the construction of subsurface reaction chambers in the form of solution cavities. We believe that raw sewage could be introduced into such cavities, and with the introduction of selected catalysts and temperature control, gas generating reactions induced.

Salt domes, in addition, offer a unique opportunity for underground storage. In north Louisiana man-made solution cavities in salt domes are presently being used on an operational basis for storage of liquid propane. This aspect of storage may be of considerable value and have tremendous potential in view of the proximity of salt domes to the site of a proposed superport in the west delta area.

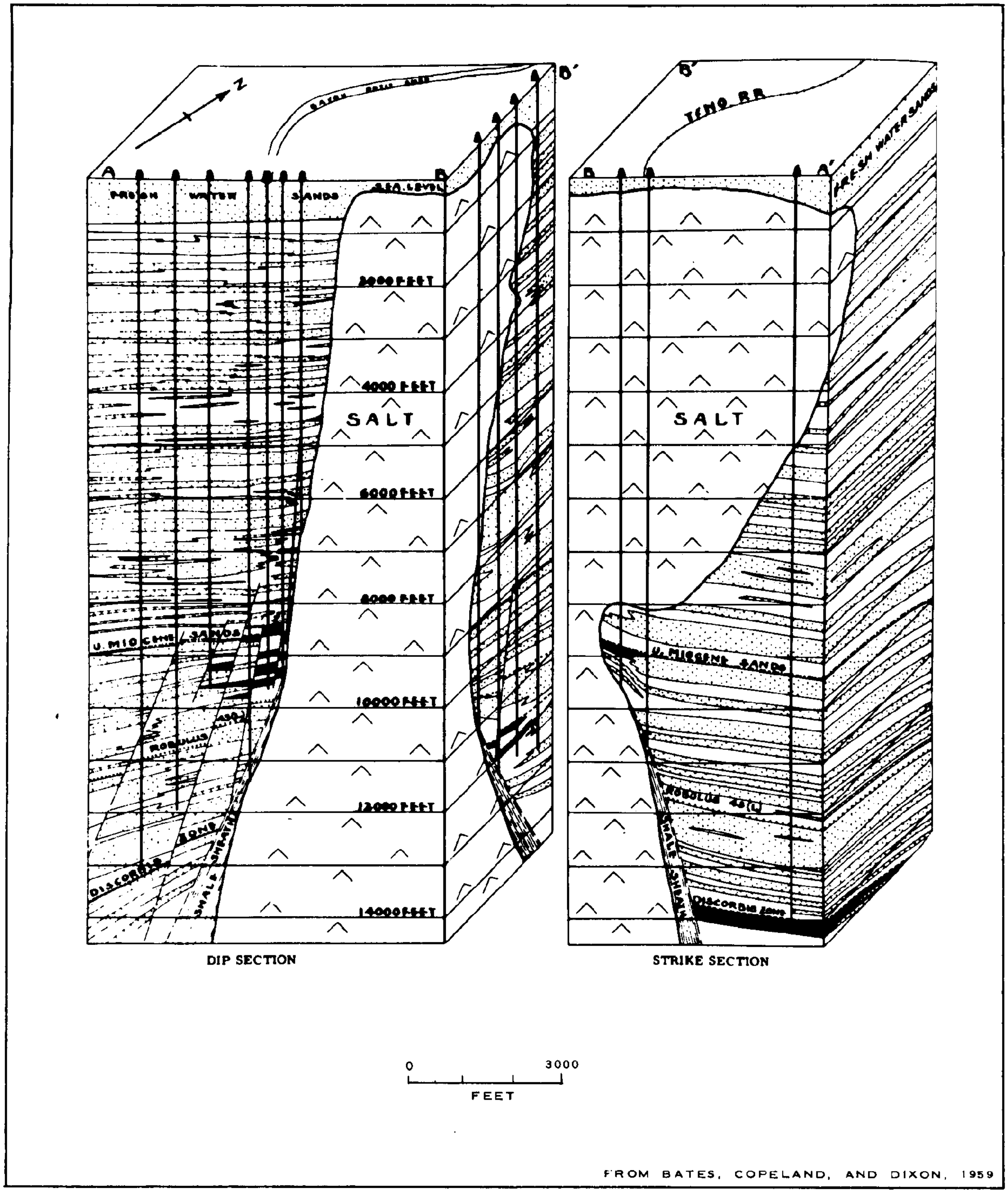

Figure 5-5. Generalized block diagram of Avery Island salt dome. (After Bates et al., 1959.)

Although a discussion of waterways is beyond the scope of this report when it concerns navigational and economic aspects, these aspects cannot be separated from coastal zone management. This is especially true when considering the Mississippi River providing access to the port of New Orleans. As stated earlier there exists a defined need for supplementary fresh water and sediment to be introduced into the coastal zone through diversion of Mississippi River flow. This means that any study dealing with improvements of deep draft access to New Orleans should consider in depth the degree to which such improvements will facilitate or impede future implementation of Mississippi River flow diversion into adjacent estuaries. Particular emphasis should be placed on developing alternatives for navigational access improvement that would require less discharge for channel maintenance, thus making this water and transported sediment available for environmental management.

In general, widening and deepening of natural channels and dredging of canals from the Gulf inland create serious environmental problems. Saltwater intrusion, accelerated runoff, and increased tidal exchange all accelerate marsh and swamp deterioration and erosion. For these reasons, any widening and/or deepening of Barataria Pass as is currently under study by the U.S. Corps of Engineers would probably have severe environmental impact on the des-Allemands-Barataria estuary system. In addition, deepening of Barataria Pass would further disrupt west to east longshore drift of sand along the Timbalier-Grand Isle barrier complex. Unless provisions for sand bypassing would be made, this would cause a deficiency in sand nourishment on Grand Terre Island (Plate 12), and, in turn, would result in accelerated erosion of the island.

The proposed alignment of the Lafourche Jump channel should be moved to the east where it would become the margin of the Lafourche Development Corridor. Spoil should be used along the western side of the canal to prevent salt water from invading adjacent bays and wetlands.

Conflicts

As development of the study area has progressed to the present point in time without the benefit of a comprehensive planning process, it is not surprising that there are conflicts in management objectives. It is important to distinguish between existing projects and land uses which are only in the planning stage. Obviously, the former represent elements and factors which are often difficult or impossible to modify, regardless of their long term undesirable effects. However, in many instances, the impact of such conflicts can be minimized by engineering modifications or restrictions prohibiting further growth or development. For example, culverts can be installed through a highway or railroad embankment that disrupts runoff. Poorly located flood protection levees having detrimental impact on wetlands can be breached. Restrictions can be developed to prohibit further drainage of wetland areas or construction therein.

Conflicts related to projects in the planning stage are easier to resolve. In many instances, changes in alignment and/or engineering design may greatly reduce conflicts and make the project compatible with regional management objectives. A good example is the recent alterations in alignment and design of Interstate 410 adopted by the Louisiana Department of Highways following an environmental impact analysis of the highway (Coastal Environments, Inc., 1973).

Cancellation of a project, even in the final stages of planning after millions of dollars have been spent in feasibility studies, may still effect a considerable savings in resources and/or dollars. However, the momentum that a project gains as the expenditure of the planning investment increases often weights the outcome of the decision heavily in favor of the proposed project, no matter how convincing the demonstration of adverse impact may be.

Another useful classification of conflicts can be made in reference to the geometry and extent of their impact. Linear conflicts, as the name implies, may extend for some distances, and may involve more than one management area. Examples are highways, railroads, pipelines, canals, levees, and power lines. Localized conflicts would include land reclamation projects, industrial sites, nuclear power plants, offshore platforms, and jetties. Examples of general conflicts are shell dredging permits, wetland drainage policy, forestry and agricultural practices, and disposal of urban and industrial wastes.

In Plate 22 of the Atlas, an attempt has been made to identify existing and proposed linear, localized, and general conflicts related to the multiuse management plan outlined in this report. A number of these projects are still in the planning stage and could be modified to reduce conflict and make them more compatible with the proposed plan. Included in this category are the Larose-Lafitte Highway, the Raceland-Gibson Highway, the Vacherie Highway, and the LOOP Pipeline and terminal facilities.

A number of proposed projects have very severe environmental implications and present severe conflicts with the proposed plan. These include the Louisiana Intracoastal Seaway, deepening of Barataria Pass, and the proposed Jefferson Parish major street plan.

Dredging and spoil disposal practices of the mineral extraction industries in general are in direct conflict with the proposed multiuse management plan, as are local and state policies related to reclamation of wetlands for urban, agricultural, and industrial development.

SUMMARY AND CONCLUSIONS

Obviously, the implications of the proposed plan are far reaching. While beneficial to some landowners, many communities, and the state and the nation in general, implementation would undoubtedly impose financial and social hardships on a considerable number of individuals. The emphasis of our studies has been on the environment and suitability of the landscape for certain uses. Although not considered here, social, economic, engineering, and legal considerations are equally important.

The necessary legislation and authority to partially implement such a plan may be already in effect. Large public works projects can be used to reinforce development corridors and to direct growth into suitable areas. Without indirect subsidy in the form of highways, flood protection, and drainage, wetland reclamation usually is not economically feasible. Further documentation of the value of renewable resources and consumer penalties associated with misuse of wetland areas will strengthen this argument.

It is fully recognized that private landowners must be compensated for loss of property rights and revenues, or for participation in environmental management programs. This has been done in other states through tax reliefs, scenic and use easements, and direct lease. Public acquisition is recommended for the most important renewable resource areas, and unique environmental and cultural features.

A continuing program of environmental and land use research, and public education is vital. Systematic ranking and evaluation of our resources and a public awareness of their value will insure responsible decisions from elected and appointed public officials. It is essential that the state and local areas gain control of their destinies. Decisions that may result in the deterioration of the environment and the quality of life of coastal zone citizens cannot be made in distant corporation board rooms or administrative offices.

We must learn more about the capacity of the region to absorb increases in population and industry. The natural systems already exhibit clear signs of imbalance. Rigid control standards must be imposed on industry. New industry must be compatible with the environmental setting.

Historic studies document that random, unplanned development in the coastal zone results in environmental destruction by attrition. Although impact of individual actions may seem insignificant, the cumulative effects are often of catastrophic proportions. For the past thirty years, the natural environment of the Louisiana coastal zone has seriously deteriorated as a result of the impact of growth and development. The deterioration is accelerating at an alarming rate. These historic changes are documented and can be measured, and future changes, if controls are not imposed, can be predicted with a high degree of probability.

This study has attempted to develop a spatial framework and some basic guidelines for mulituse management of south-central Louisiana. Emphasis is placed on environmental management, but the need for continued economic growth is also recognized and weighed heavily in the planning process. Clearly, the plan is not all inclusive, nor are the lines sacred. The plan has, however, been erected upon a firm data base and follows a methodology that can be tested.

An attempt has been made to keep the plan at a level of resolution that would be most compatible with the work of other agencies. Hopefully it will intermesh with the efforts of the various regional, parish, and municipal planning offices as well as those of other local, state, and federal agencies.

It should be emphasized that planning is a process and a specific plan is only a summary of the status of the process at a particular time. For this reason, the study should be regarded as open-ended. The Atlas has been designed so that additional sheets may be issued at future dates. Hopefully, these additions will not only present new data, but will also show more specific versions of the plan as the level of effort is progressively focused to smaller and smaller units.

The approach developed and recommendations made for the study area should have broader applications in the state of Louisiana, as well as in other coastal regions.

APPENDIX A

FLIGHT LINES AND DATA SUMMARY
OF
REMOTE SENSING MISSIONS
OVER
BARATARIA-TERREBONNE AREA

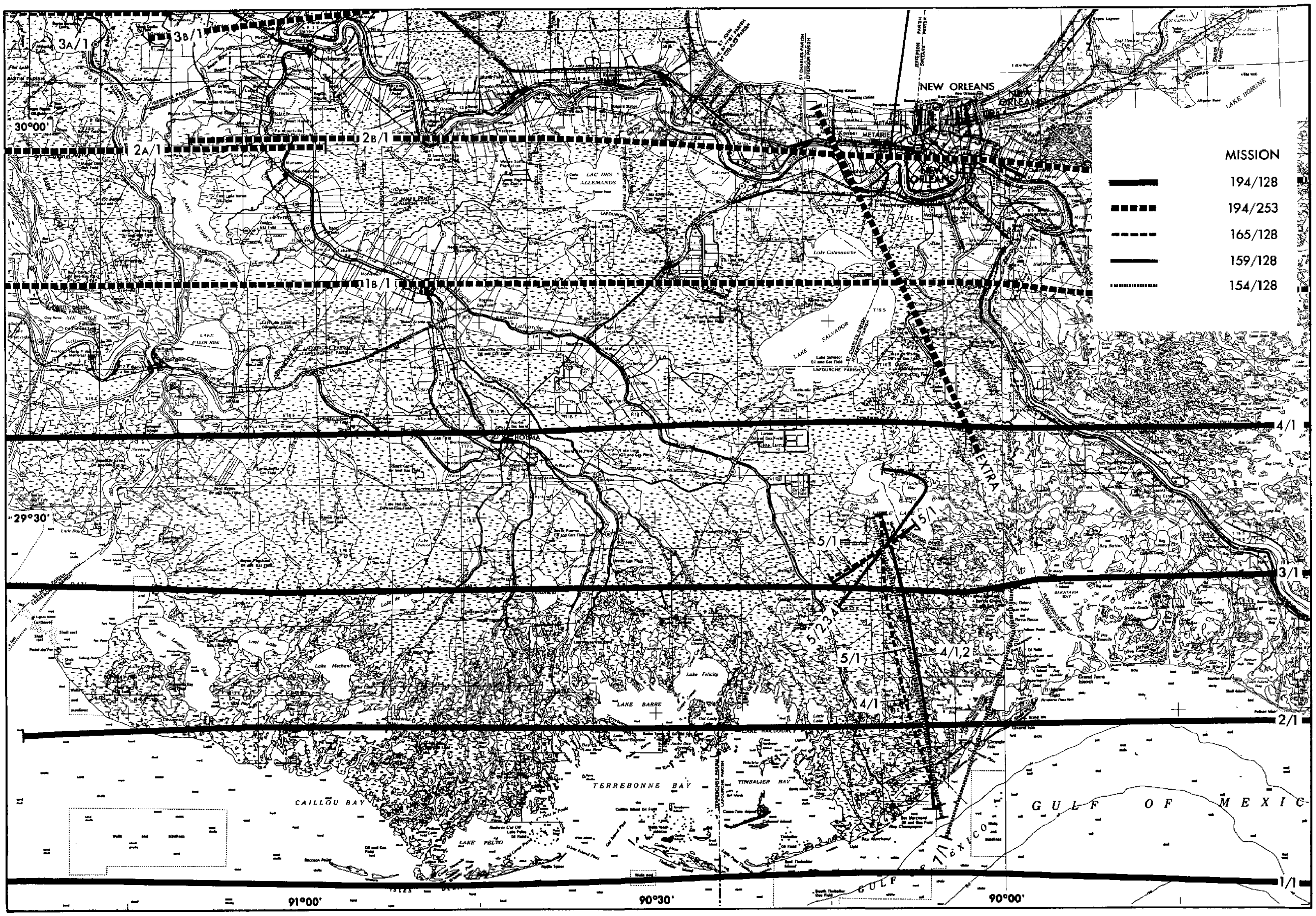
MISSION
194/128
194/253
165/128
159/128
154/128
NEW ORLEANS
LAKE SALVADOR
LAC DES ALLEMANDS
LAKE BORGNE
TERREBONNE BAY
TIMBALIER BAY
CAILLOU BAY
LAKE BARRE
LAKE PELTO
GULF OF MEXICO
EXTRA
1/1
2/1
3/1
4/1
2A/1
2B/1
1B/1
3A/1
3B/1
5/1
4/1,2
5/2,3,4
7/1
30°00'
29°30'
91°00'
90°30'
90°00'

TABLE 1B

INSTRUMENT SUMMARY, MISSISSIPPI DELTA

LINE	RUN	LAT. / LONG. (beginning)	LAT. / LONG. (end)	TIME	ALT. / 10^3 ft.	LINE DISTANCE (miles)	MISSION 154/TEST SITE 128			10/23/70		FLIGHT 6		AIRCRAFT	
							SENSOR	RC-8/1	RC-8/2	Hass 1	Hass 2	Hass 3	Hass 4	Hass 5	Hass 6
							FOCAL LEN.								
							FILM	SO 397	SO 246	2402	2402	2402	2402	2424	2402
							FILTER	Cl. AV	0.7 pm	47B	58	25 A	2E+38	89 B	21 + 57
							ROLL NO.	38	39	24	25	26	27	28	29
5	1				6.3		Bayou Moreau to Lake Inferme Gas Field.								
7	1				6.3		Pelican Point through Grande Isle into Gulf of Mexico.								
							MISSION 154/TEST SITE 128			10/21/70		FLIGHT 3		AIRCRAFT	
							ROLL NO.	4	5	18	19	20	21	22	23
5	1				6.0		Reflown.								
5	1				6.0		Reflown. Bayou Moreau to Ground Lake.								
7	1				6.0		Reflown. Bayou Cholas through Grande Isle to Gulf of Mexico.								

TABLE 2A

TEST SITE AND OPERATIONS SUMMARY
MISSISSIPPI DELTA/BARATARIA BAY

Test Site - 128

Principal Investigator
Dr. W. G. McIntire

Flight Operations

Barataria Bay

1. 2 flight lines - 2 altitudes (6000 and 3000 feet).
2. 3 flights required - flooding tide, ebbing tide, and night flooding tide.
3. Strobe lights at each end of Line 5 at night.
4. Line 5 only line to be flown at Barataria at night.

TABLE 2B

INSTRUMENT SUMMARY, MISSISSIPPI DELTA/BARATARIA BAY

MISSION / TEST SITE					FLIGHT		AIRCRAFT	
SENSOR	RC 8	RC 8	Hass 1	Hass 2	Hass 3	Hass 4	Hass 5	Hass 6
FOCAL LEN.	6 in.	6 in.	40 mm	40 mm	40 mm	40 mm	40 mm	40 mm
FILM	SO246	2443	2448	2443	2402	2402	2402	2424
FILTER	0.70	0.52	HF 3	15	47 B	58	25	89 B
ROLL NO.	36	37	38	39	40	41	42	43

LINE	RUN	LAT. / LONG. (beginning)	LAT. / LONG. (end)	TIME	ALT. / 10^3ft.	LINE DISTANCE (miles)	
4	1	29° 30' N 90° 08' W	29° 07' N 90° 04' W		5.9	22	East of Bay Marchand to north of Round Lake. Magnetic heading of 355°.
*5	1	29° 29' N 90° 09' W	29° 25' N 90° 12' W	FLOOD TIDE	5.9	6	South of Turtle Bay to northeast of Golden Meadow.
*5	2	same as line5/1	same as line 5/1		2.9	6	Southeast of Golden Meadow to Turtle Bay, then west to north Little Lake. Magnetic heading 035°.
4	2	same as line 4/1	same as line 4/1		2.9	22	Same coverage as Line 4/Run 1, using magnetic heading 175°.
*5	3	same as line 5/1	same as line 5/1		6.0	6	Not plotted. Same as Line 5/Run 2.
5	4	same as line 5/1	same as line 5/1		3.0	6	Not plotted. Same as Line 5/Run 2. Magnetic heading 215°.

*Extra flights flown 3/5/71.

TABLE 3A

TEST SITE AND OPERATIONS SUMMARY

MISSISSIPPI DELTA/BARATARIA BAY

Test Site - 128

Application Discipline
Hydrology

Organization
Coastal Studies Institute
Louisiana State University
Baton Rouge, Louisiana 70803

Principal Investigator
W. G. McIntire

Site Coordinator
L. D. Wright/
W. G. Smith

Mission Manager
Frank Newman

INVESTIGATION OBJECTIVES

Barataria Bay

To monitor (on a seasonal basis) vegetational changes and erosion along the shoreline of small lakes and bays that contribute to land loss and coastal deterioration.

To obtain information on turbidity characteristics of coastal water bodies.

To relate these data to environmental factors currently under study by Louisiana State University Sea Grant and Coastal Studies Institute researchers.

Flight Operations

Barataria Bay

1. 2 flight lines - two altitudes (15,000 and 3,000 feet).
2. 2 flights required - one daytime and one night slack tide. Strobe lights at each end of Line 5 at night.
3. Only Line 5 to be flown at Barataria Bay at night.

TABLE 3B

INSTRUMENT SUMMARY, MISSISSIPPI DELTA/BARATARIA BAY

MISSION 165/ TEST SITE 128		5/16/71		FLIGHT 1	AIRCRAFT NC130B		
SENSOR	RC 8	RC 8	KA 62/3	KA 62/4	KA 62/5		
FOCAL LEN.	6 in.	6 in.	3 in.	3 in.	3 in.		
FILM	2424	2443	SO397	2402	2402		
FILTER	89 B	W 12	N/A	25 A	47 B		
ROLL NO.	1	2	3	4	5		

LINE	RUN	LAT. / LONG. (beginning)	LAT. / LONG. (end)	TIME *	ALT. / 10^3ft.	LINE DISTANCE (miles)	
4	1	29° 08' N 90° 05' W	29° 29' N 90° 10' W		15.1	30	Bayou Moreau, off coast, to Little Lake. Magnetic heading 334°.
5	1	29° 29' N 90° 09' W	29° 26' N 90° 12' W	morning	15	10	Little Lake to Golden Meadow. Magnetic heading of 241°.
5	2	same	same	night	3	10	Same area as Line 5/1. Magnetic heading of 239°.
4	2	same	same		3.1	30	Same area as Line 5/1. Magnetic heading of 168°.

* Flooding Tide. Data correction starts approximately 3 hours before high tide.

TABLE 4A

TEST SITE AND OPERATIONS SUMMARY

LOUISIANA UPPER DELTAIC PLAIN

Test Site - 253

Principal Investigator
S. M. Gagliano

Application Discipline
Geography

Site Coordinator
R. E. Becker

Organization
Louisiana State Universtiy
Baton Rouge, Louisiana 70803

FLIGHT OBJECTIVES

The objectives of the flight are to support an investigation to develop schemes for comprehensive water resource management and use inventory which will be of value in operational programs of the Corps of Engineers. The overflight will acquire small-scale multispectral photography which will be used to develop methods for regional land use and hydrologic patterns of the upper Louisiana Deltaic Plain during a season when vegetal ground cover is at a minimum.

TABLE 4B

INSTRUMENT SUMMARY, LOUISIANA UPPER DELTAIC PLAIN

MISSION 194	TEST SITE 253		3/16/72		FLIGHT 1		AIRCRAFT-RB57F	
SENSOR	RC8/4R	RC8/4L	Hass 1	Hass 2	Hass 3	Hass 4	Zeiss	Hass 5
FOCAL LEN.	6 in.	6 in.	40 mm	40 mm	40 mm	40 mm	12 in.	40 mm
FILM	SO 397	2443	2402	2402	2424	SO 356	SO 397	2443
FILTER	2A	510pm	25 A	57	89B	N/A	2 A	12+30B
ROLL NO.	1	2	4	5	6	7	3	8

LINE	RUN	LAT. / LONG. (beginning)	LAT. / LONG. (end)	TIME	ALT. / 10^3ft.	LINE DISTANCE (miles)	
2a	1	29° 58'.5 90° 58'.8	29° 57'.5 94° 01'.3		60	276	Beaumont, Texas to Napoleanville, Louisiana.
1b	1	29° 47'.3 91° 41'.8	29° 47'.7 89° 10'.3		60	276	Weeks Island, Louisiana to Chandeleur Sound.
2b	1	29° 55'.3 89° 17'.5	29° 50'.7 91° 10'.2		60	276	Drum Bay to Lake Verret.
Extra	1	30° 01'.0 90° 15'.2	29° 34'.7 90° 02'.5		60		3 miles Northwest of New Orleans to 10 miles south of New Orleans.

TABLE 5A

TEST SITE AND OPERATIONS SUMMARY

MISSISSIPPI DELTA/BARATARIA BAY/ATCHAFALAYA BAY

Test Site - 128/253

Application Discipline
Oceanography

Organization
Louisiana State University
Coastal Studies Institute
Baton Rouge, Louisiana 70803

Principal Investigator
W. G. McIntire

Site Coordinator
R. E. Becker

FLIGHT OBJECTIVES

1. To map regional patterns of outflow and effluent dispersion from all Mississippi River distributaries (including the Atchafalaya).

2. To correlate with winds, tides, and seasonal factors including river stage and precipitation budget.

3. To calibrate plume areas with gaged discharge at Vicksburg, Mississippi (total flow) and Simmesport (Atchafalaya flow).

GROUND REQUIREMENTS

Ground truth - temperature, salinity, and wind observations will be performed at Grand Isle and Atchafalaya Bay during overflight.

TABLE 5B

INSTURMENT SUMMARY, MISSISSIPPI DELTA/BARATARIA BAY/ATCHAFALAYA BAY

MISSION 194 / TEST SITE 128/25B	3/17/72			FLIGHT 3		AIRCRAFT RB57F		
SENSOR	RC8/4R	RC8/4L	Zeiss	Hass 1	Hass 2	Hass3	Hass 4	Hass 5
FOCAL LEN.	6 in.	6 in.	12 in.	40 mm	40 mm	40 mm	40 mm	40 mm
FILM	SO 397	2443	SO 397	2402	2402	2424	So 356	2443
FILTER	2 A	510 pm	2 A	57	25 A	89 B	N/A	12+30B
ROLL NO.	12	13	14	15	16	17	18	19

LINE	RUN	LAT. / LONG. (beginning)	LAT. / LONG. (end)	TIME	ALT. / 10^3ft.	LINE DISTANCE (miles)	
1	1	29° 02'.4 88° 41'.0	29° 02'.4 91° 43'.0		60	140	From 25 miles east of Garden Island Bay to 40 miles west of Caillou Bay, Louisiana.
2	1	29° 13'.3 91° 23'.8	29° 14'.2 88° 42'.7		60	140	From 10 miles southwest of Point Au Fer Island to 20 miles east of Delta National Wildlife Refuge.
3	1	29° 25'.5 88° 46'.8	29° 24'.6 91° 42'.3		60	140	From 25 miles east of Breton Island to 5 miles South of Marsh Island.
4	1	29° 39'.1 92° 32'.2	29° 37'.4 88° 37'.3		60	140	White Lake to 15 miles southeast of Chandeleur Islands.

APPENDIX B

AGENCIES AND GROUPS CONTACTED DURING STUDY

User input for this study was obtained through personal interviews, attendance of public hearings, participation in meetings and lectures to special interest groups. Primary lectures and contacts are listed below.

Oral Presentations

American Public Works Association. New Orleans City Planning Commission in New Orleans, February 17, 1972.

Environmental Problems in the Louisiana Coastal Zone. Sierra Club Chapter Wide Conference, Bunkie, Louisiana, February 20, 1972.

Coastal Zone Management Techniques. Louisiana Coastal Marine Resources Commission, March, 1972.

A Positive Approach to the Environment in Coastal Louisiana. Louisiana Intracoastal Seaway Association, Lafayette, Louisiana, April 8, 1972.

Environmental Enhancement through Controlled Sedimentation in the Mississippi Delta. Symposium on Sedimentary Environments, Society for Economic Paleontologists and Mineralogists, Environmental Research Group, Denver, Colorado, April 16, 1972.

General Impact of Plans and Proposals that Affect Estuary System in Louisiana. Student Government Assn., Dept. of Environmental Affairs, LSUNO, April 22, 1972.

Coastal Zone Planning and Development. LSU Sea Grant Program, Baton Rouge, La., May 9-10, 1972.

Guest Lecture. Southeastern Louisiana University, Hammond, La., June 27, 1972.

Environmental Management in Coastal Louisiana. Mobil's Environmental Conference, New Orleans, Louisiana, Sept. 6-7, 1972.

Panel Discussion on I-410. New Orleans Group of the Sierra Club, Sept. 10, 1972.

Encroachment of Urban Development on Wetlands in the New Orleans Area. Orleans Audubon Society, Sept. 18, 1972.

Environmental Analysis for Coastal Zone Planning and Urban Encroachment in the New Orleans Area. LSU Sea Grant/Industry/Government Program, Baton Rouge, La., Sept. 30, 1972.

Toward Environmental Management of the Louisiana Coastal Zone. Sierra Club, Baton Rouge, La., Oct. 22, 1972.

Environmental Problems in Coastal Louisiana. Louisiana Attorney General's Environmental Advisory Committee, Baton Rouge, La., Oct. 26, 1972.

Proposed Management and Development Plans. RUBY Conference for Louisiana Wetlands, Environmental Management Research Lab, Oct., 1972.

Changes to the Environment that Progress Has Brought. Consulting Engineers Council of Louisiana, Inc., New Orleans, La., December, 1972.

Man's Impact on Marshlands. AAAS Symposium, Washington, D. C., Dec., 1972.

Urban Growth in Louisiana Wetlands. Castle Manor Improvement Assn., Inc., New Olreans, La., January 16, 1973.

Public Works and Urban Growth, Transportation. Latin American Studies Institute, LSU, Baton Rouge, La., Feb. 22, 1973.

Coastal Zone Resources and Management. Soil Scientist Workshop, Alexandria, La., Feb. 27, 1973.

Environmental Management in Coastal Louisiana. Lafayette Rod and Gun Club, Lafayette, La., Nov. 10, 1973.

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